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Lubrication

A Technical Publication Devoted to
the Selection and Use of Lubricants

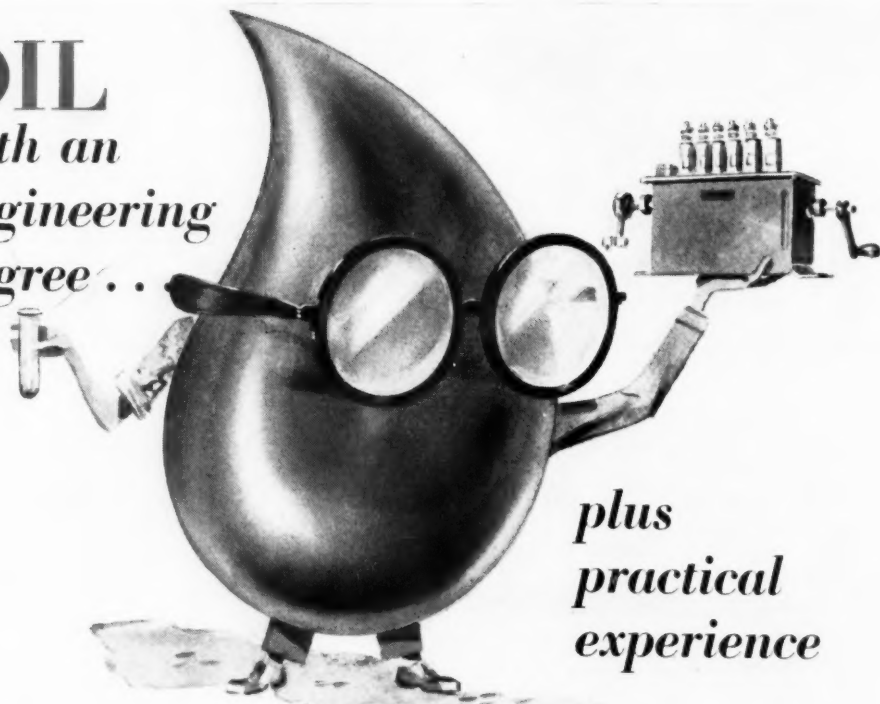
THIS ISSUE

GRAIN HANDLING
AND
FLOUR MILLING
MACHINERY



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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Grain Handling and Flour Milling Machinery

GRAIN HANDLING and flour milling requires the moving of large quantities of materials under conditions which often may develop problems in lubrication. The machinery must run continuously for long periods of time. In some Northern areas conveyors in the elevators run virtually at atmospheric temperatures for several months during the winter. Dust must be removed because it can develop an explosion hazard. All this means that the machinery must operate dependably, through effective lubrication.

Power and its utilization obviously is an important item. Lubrication, as an adjunct to economical use of power is equally as important. Since grain elevator equipment operates without the benefit of any heat, special consideration must be given to keeping lubricant "drag" at a minimum by using carefully selected oils and greases. A surprising amount of power can be lost in turning cold conveyor troughing rolls and return idlers, as hundreds of these are required for the long belts which are used.

Grain handling and flour milling are completely

mechanized procedures today. Milling has always been a more or less mechanical process although in the beginning it involved hand or animal power.

When our forebears discovered that water-power could be used effectually for turning the rolls, they revolutionized the process. Modern improvements in conveying methods along with automatic methods of car-unloading and removing grain from holds of ships, have been equally revolutionary advancements.

HANDLING MACHINERY AT THE ELEVATORS

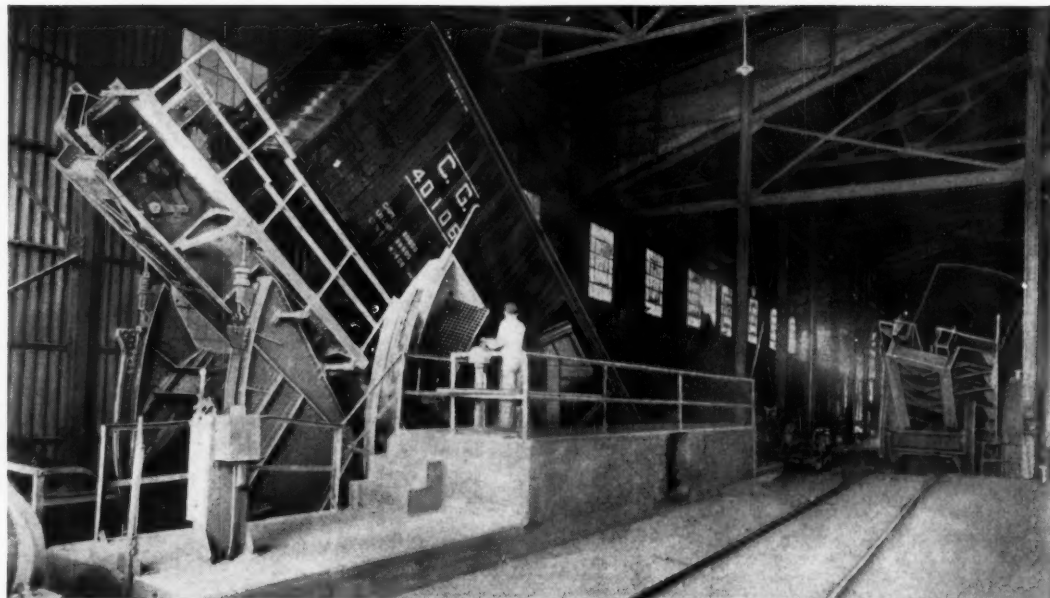
The popularity of the motor driven conveyor has been impelled by the applicability of the unit type of drive. Motors also drive the blowers, and exhausters for creating vacuum up to 8 inches when grain is to be removed from holds of ships by suction. Induction type motors are used

for such drives to reduce the possibility of arcing and dust explosion. The elevator people, however, do not rely entirely upon this precaution; they also provide means to prevent dust accumulation by installing suction dust-gathering devices located at

THE machinery required for grain handling in its removal from ship's holds or grain cars, and for subsequent storage, sorting and blending in the modern elevator, has received careful attention by materials handling authorities. Grain is a comparatively perishable product. As such, it is subject to rapid deterioration through premature fermentation. It is also a decided hazard due to possibility of dust explosion.

The machinery required later for milling and grinding must operate equally as efficiently as the elevator equipment to avoid any possible backing up of product. This issue of "Lubrication" explains the different types of conveyors, methods of individual drives, and means for dust control and removal; also the basic mill processes and machines. Lubrication of their mechanisms with regard to the operating conditions is discussed in detail.

The high degree of coordination which has been attained in planning the arrangement of such equipment, its lubrication and the extent to which such coordination has reduced handling costs (which must of necessity be passed on to us—the ultimate consumers) should appeal to everybody.



Courtesy of Link-Belt Company

Figure 1—A Link-Belt grain car unloader which consists of a structural steel cradle so mounted on rollers at four points as to permit endwise tipping to 40 degrees from the horizontal in either direction; and of a car supporting platform, pivotally mounted to permit sidewise tipping to an angle of 15 degrees in one direction.

strategic points with respect to the conveyor belts.

Anti-friction bearings and unit type of reduction gear drives are well adapted to grain handling service. Safety of personnel is decidedly affected by their usage, inasmuch as their location in certain parts of the elevator may often be hazardous, even for re-lubrication, not to mention repair. The use of equipment which will reduce the necessity for frequent re-lubrication and lengthen the machine's useful life is therefore of material advantage.

Prevention of dust accumulation benefits lubrication in that possibility of contamination of bearing, gear and chain lubricants is reduced, thus enabling them to more effectively perform their intended functions. Reduced maintenance and replacement costs and marked increase in power economies follow especially when properly designed sealed housings for bearings, chains, and reduction gears are provided.

TEMPERATURE MUST BE CONTROLLED

Temperature control is essential in the handling of grain and finely ground cereal flours especially when the former may be damp and apt to develop chemical action, which will cause rise in temperature. Between individual particles this is not serious but the cumulative effect of millions of such particles packed in close contact must be considered. For this reason, great care is taken to control bin temperatures, by blasts of cold air. This also prevents pre-

mature fermentation of grain which might otherwise occur under high temperatures, and decreases the possibility of dust explosions, which have a direct relation to temperature and the dust content of the air.

The requirement of large quantities of air for the movement of grain or for the elimination of dust, creates the need for high capacity fans and blowers. The importance of these units necessitates faultless design and effective lubrication to insure continuous operation.

GRAIN CONVEYORS

Grain conveyors are built for endurance and hard service. Several types are used, i.e. the screw, ribbon, bucket or belt design.

The screw type, which is essentially a stamped or rolled steel spiral, secured by lugs or welded to a pipe shaft, and the ribbon conveyor which consists of a ribbon flight similarly secured to the shaft with an open space between the ribbon and shaft, are subject, probably, to the most severe service.

The screw, or as it is sometimes termed, "the spiral conveyor," is designed for horizontal moving of dry materials or on inclines up to 15 degrees, with reduced capacity. It is constructed to revolve in a box of steel, wood, cast-iron or concrete, according to the nature of the materials to be handled. The screw shaft normally is carried by plain bearings which are grease lubricated.

The bucket conveyor is the principal elevating medium in the handling of grain, by means of

bucket-shaped receptacles. It can be constructed for vertical as well as horizontal service. Constructional features vary but the principles are similar in all. These conveyors will handle practically any material which will not adhere to the containers. A bucket conveyor usually consists of a belt to which the buckets are attached. It may be vertical or inclined and have continuous or non-continuous buckets. The discharge and in-take of such a conveyor will depend upon the locality, material to be handled, and the general purposes for which handling is carried out.

Belt conveyors involve an endless belt of fabric or rubber designed to travel over pulleys at the conveyor ends, the loaded section being supported on troughing idlers at the sides which allow the belt to form into a trough. The empty belt is supported on straight idlers. Such a conveyor will handle any material in bulk which will not adhere to it, and which can be properly fed thereto. Belt conveyors are very widely used for handling grain over the bins. The length of these conveyors in the modern elevator requires the use of hundreds of idlers of either plain or anti-friction bearing type. Lubrication of these bearings can be most efficiently accomplished through the use of a short fibre, mixed-base grease. This is most important when temperatures are low in that this type of grease offers "quick shear" or "low lubricant drag" allowing the belt to be brought up to normal operating speed with a minimum of power demand. This type of grease

will also form an effective collar or seal at the end of the bearing which excludes dust and keeps wear to a minimum.

Motor and Conveyor Bearings

The electric motor is the predominating prime mover in the grain elevator as well as the flour mill, operating through chain drives or speed reduction gears. The manner of installation, however, will vary according to location of the various driven elements. Group driving from a common source of power transmission will be practicable in some elevators; in others individual drive to each exhaust, suction blower or conveyor will prevail.

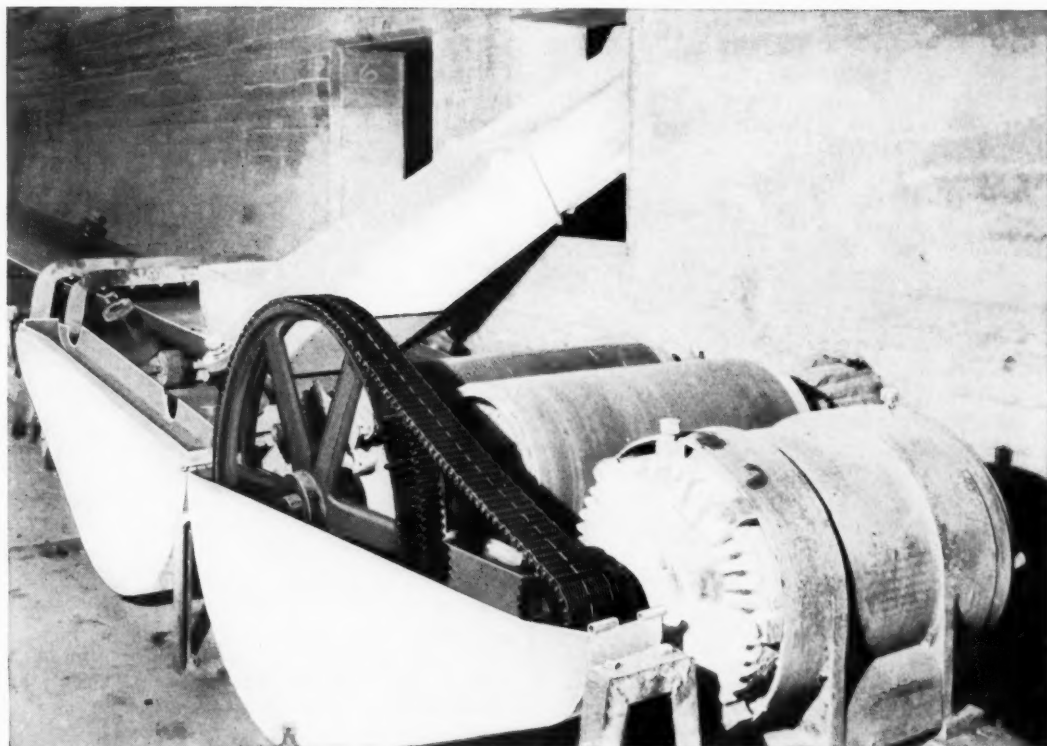
Regardless of the type of installation, lubrication is most important, especially where gears and bearings are in close proximity and there is possibility of contamination of lubricants by dust. When the anti-friction bearing was made available it enabled design and construction of bearing housings which could be more readily sealed against entry of dust. Both ball and roller bearings have been successfully applied to grain elevator and mill motors, in general designed for grease lubrication by the same grease as used on comparable conveyor bearings.

The selection of lubricants for anti-friction bearings, must be studied with full-realization of the difficulties which may result from use of an unsuitable product. Best results will be obtained from a grease of normal consistency, capable of functioning at high temperatures to insure against breakdown and separation, although, in general, motor, con-



Courtesy of Link-Belt Company

Figure 2—A Link-Belt silent chain drive (with upper half of oil retaining case removed) to a 42 inch wide 780 foot long grain handling belt conveyor over storage silos.



Courtesy of Link-Belt Company

Figure 3—A 40 H.P. silent chain drive 36 inch centers, 1170 to 170 R.P.M. at a grain elevator.

veyor and blower bearings in the elevator and mill will seldom exceed 125°F., in average service.

Yet, over-heating in the bearing itself may occur in direct relation to the amount of lubricant used, particularly if this latter is a grease. If it is too heavy or inert, an excessive quantity in any anti-friction bearing may lead to a considerable rise in temperature due almost entirely to internal friction within the grease itself. Obviously were this to continue explosion temperatures might be approached, should there be any appreciable amount of dust present in the air surrounding the bearings in question. In view of the necessity for guarding against over-lubrication, careful elevator operators observe a regular schedule for greasing all anti-friction bearings, applying but a very small amount of fresh grease at intervals of from one to three months, according to the location of the bearings, the tightness of the housings, and the time operated. Electric motor bearings must be very carefully lubricated, for use of grease to any appreciable excess may lead to rupture of the seal and fouling of the windings. This will be aggravated where windage, or draft occurs through the bearings and motor. Moisture might, in turn, cause arcing and sparks, which in the presence of grain dust might result in an explosion.

For this reason explosion-proof motors are very widely used.

Speed Reduction Gears

The enclosed type speed reducer has a definite place in grain elevator service. As the primary element in transmission of power to conveying equipment, and the various machines in the subsequent grinding and screening operations the speed reducer is a dominating factor.

The modern, oil-tight, dust-tight gear case is a decided adjunct to effective lubrication and prevention of wear. The essential characteristics of a good gear lubricant are that it shall provide protection to the gears and bearings through the provision of a strong film of oil that will resist rupture even under abnormal loads. These gears and bearings are highly finished and must also be protected by the lubricant against rusting and corrosion during idle periods. Extreme caution should be used at all times in the handling of these gear oils to keep them clean. Grain dust is abrasive and if it is not kept out of these housings rapid wear will ensue.

Where gears operate in housings that are not oil or dust tight, relubrication is necessary at shorter intervals to remove the contaminated lubricant. The

LUBRICATION

lubricant must of necessity be of a type that will not allow the oil and dust mixture to build up on the gear teeth as excessive bearing pressures will occur in addition to excessive wear.

Lubrication recommendations are made based on operating conditions and design, so the lubrication engineer must develop the best practices possible to meet and serve the conditions existing. To a certain extent recommendations are possible for alteration in bearing design, or gear and bearing protection against dust, but the changes must actually be carried out by the mechanical organization of the plant.

Watch the Oil Level

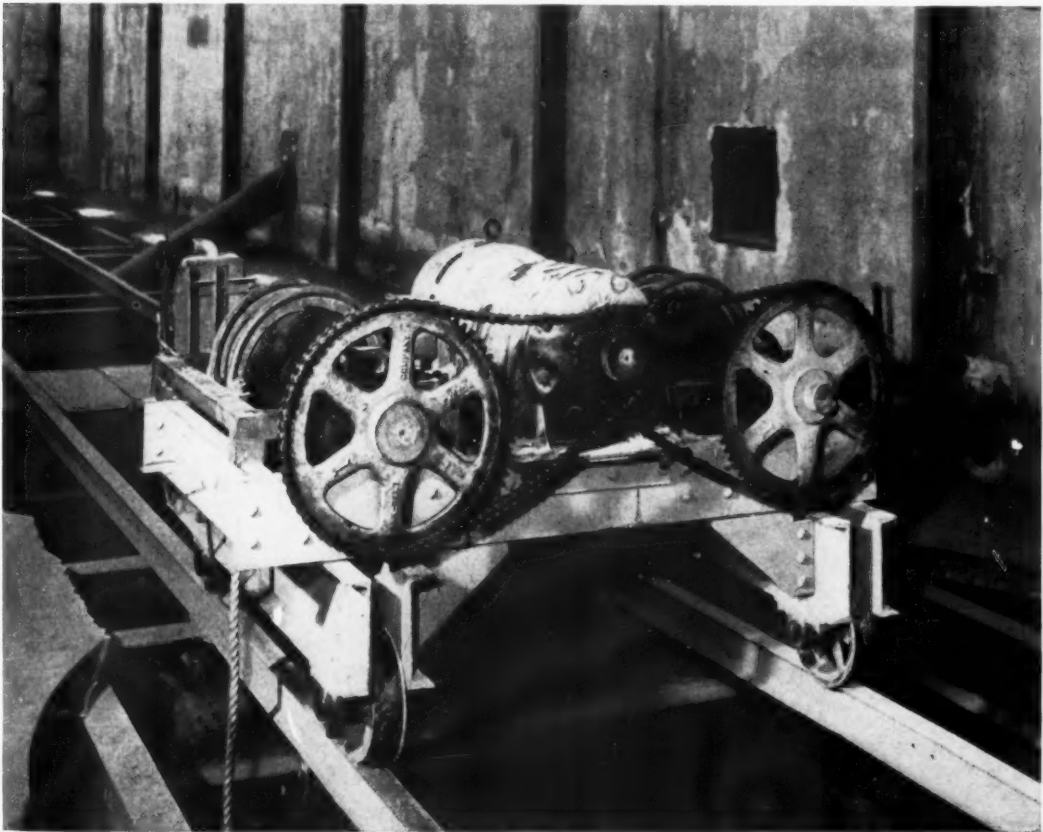
Where gears are bath lubricated, the oil level should be sufficiently high to insure suitable dipping of the teeth of the lower gear. Submergence of too much of the gear or pinion is not advisable and, as a general rule, unless comparatively fluid oils are used, it will not be necessary. The teeth will carry enough oil up to those of the companion gear.

With heavier gear lubricants, it will be possible to run with a somewhat lower level than where more

fluid products are used. It is for this reason that reduction gear units are usually equipped with an external gauge glass to enable the operator to observe at all times just what level he is carrying.

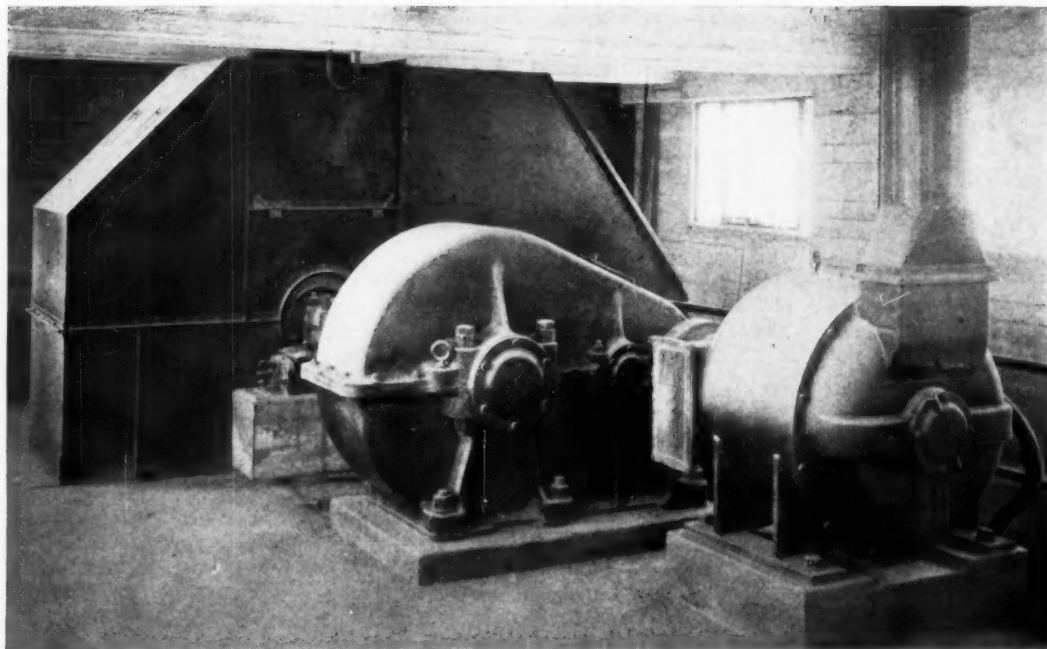
The Geared Motor

The geared motor is well suited to blower and conveyor service due to its unit housing design and facilities for automatic lubrication. In this unit the bearings are similar to the bearings of the modern type of motor, being largely anti-friction, designed for grease lubrication. The reduction gear set, however, is designed for oil lubrication, the oil being contained in a bath at a sufficient level to insure proper dipping of the lower gear teeth. As a general rule, it is advisable to keep the oil bath at the level recommended by the manufacturer which is normally from one-third to one-half full, so that the bottom gears will be about half submerged. According to the temperatures of operation and extent to which heat may be transmitted to the gear case from the motor itself, an oil of from 500 to 900 seconds Saybolt Viscosity at 100°F. is used at normal tem-



Courtesy of Link-Belt Company

Figure 4—Two Link-Belt roller chain drives to a power shovel in a grain elevator.



Courtesy of Link-Belt Company

Figure 5—Showing a 125 H.P. Link-Belt D-18 double reduction tandem type herringbone gear speed reducer operating lofter legs.

peratures; at low temperatures it is necessary to use an oil of good pour test to insure adequate fluidity and reduction of drag.

DUST CONTROL

The dust content of the air in the modern grain elevator must be kept down to prevent explosions and fires. There is an added advantage, however, in that personal welfare of employees is increased and cleanliness around equipment is improved. For this purpose, the suction blower or exhaustor is a valuable piece of equipment. Normally but a slight amount of vacuum is required to remove effectively all dust from grain as it passes over conveyors. In the early stages of handling, however, where the grain itself is actually moved by suction, for example with suction unloaders, a vacuum of up to 8 inches may be necessary.

The bearings of blowers and exhaustors are very similar to the motor bearings found in the grain elevator or mill being either fitted with ring oilers or ball or roller bearings. Their lubrication requirements also are comparable to those of the motors.

Ring oilers provide a flood of oil which is constantly passed through the bearings, thereby washing out any grit, dirt, dust or metallic particles that may have gained entry. On account of this washing action of the oil, however, the reservoir will gradually tend to accumulate a certain amount of sedimen-

tary deposits. Therefore, it should be flushed out and cleaned at periodic intervals, the old oil being replaced with a fresh charge. In elevator and mill practice a good quality straight mineral oil of around 300 seconds Saybolt Universal Viscosity will be used at normal temperatures.

Where ball or roller bearings serve to support the journals of fans, rotors or impeller, each is individually lubricated periodically. Prevention of corrosion in such bearings, is regarded by many as perhaps the chief function of the lubricant, rather than actual reduction of friction or removal of heat. Grease is generally used for this purpose. It should be a high quality anti-friction bearing grease specifically prepared to resist chemical or physical change.

All fans and blowers, however, will not require or be equipped with ring oilers or anti-friction bearings. In certain cases plain bearings lubricated by grease cups, pressure gun fittings or sight feed oiling devices may be regarded as suitable by the builders, especially where operation is to be more or less intermittent. For such service a medium bodied engine oil or a medium grade of compression cup grease can be used.

Driving Chains

Lubrication of driving chains requires careful study of operating conditions, including such fac-

LUBRICATION

tors as speed, load, clearances and extent of bending or articulation. Speed is important, since it involves the frequency of shocks due to engagement of the chain links with the gear or sprocket teeth. In other words, the greater the speed the more frequent will be the shock on each link. Whether or not shocks of this nature will be detrimental to lubrication will depend upon the load and constancy of operation. Rapid repetition of such shocks upon the bearing points of the chain may tend to force or squeeze the lubricating film out from between moving elements. Lubrication is most effective when means are provided for constant renewal of the lubricating film on the chain links. Some designs develop splash lubrication. Splash lubrication can be attained by means of a disc attached to one side of the main shaft. As the wheel rotates the disc dips into the oil in the base, and throws it to the top of the casing, which is built in the shape of a wedge.

As a result, there is a continuous and uniform dripping of oil upon the chain. In casings of this type, the oil level is below the chain, the disc dipping in it to a depth of somewhat less than one inch. Where bath lubrication prevails, however, the oil

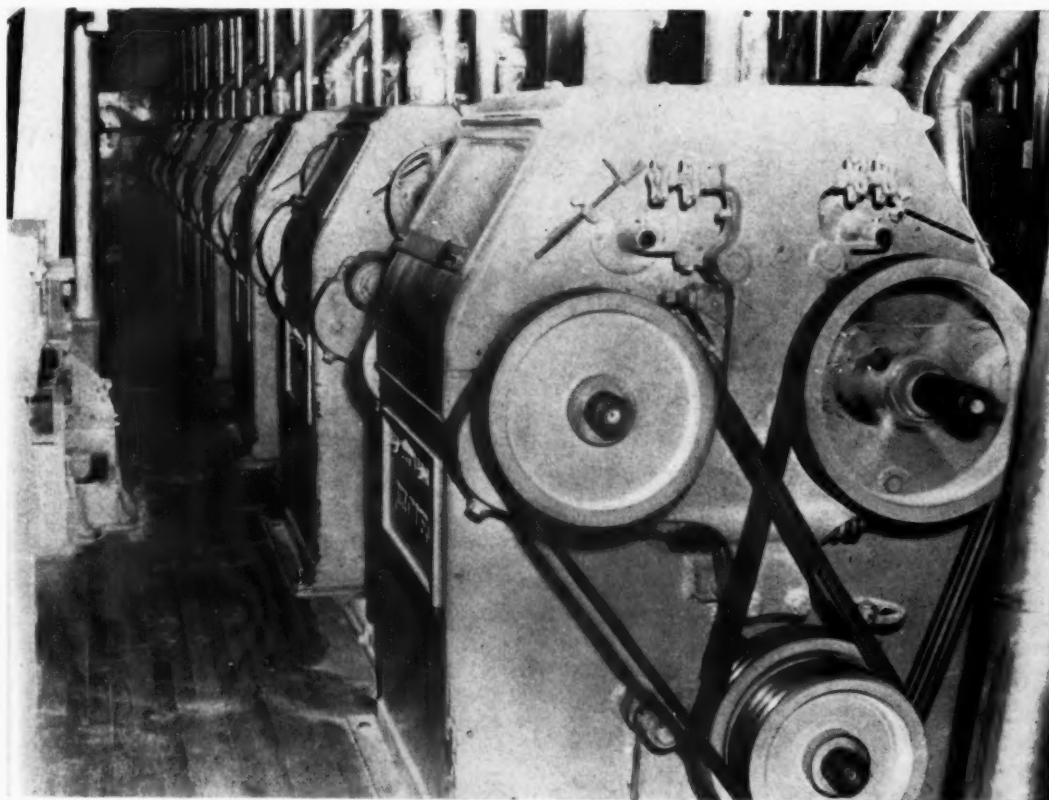
level should be somewhat above the lowest part of the chain. Casings which are used on high speed chains, in turn, are often equipped with an oil pump, the oil being sprayed upon the chain under relatively constant pressure.

Exposed chains are lubricated by brushing the lubricant uniformly over the driving surfaces, or by removal and immersion of the entire chain. Some chains of this type are treated with the lubricant before they leave the factory. Usually a soaking bath is used, the chains being immersed for a sufficient length of time to allow penetration to all interior parts.

Silent chains require the use of a relatively fluid straight mineral lubricant. When chains are encased, if they are to be bath lubricated an engine oil having a viscosity of about 500 seconds Saybolt Universal at 100 degrees Fahr., will be suitable. Where exposed or encased but not submerged in oil, a heavier product, such as a mineral cylinder oil or light gear lubricant is advisable.

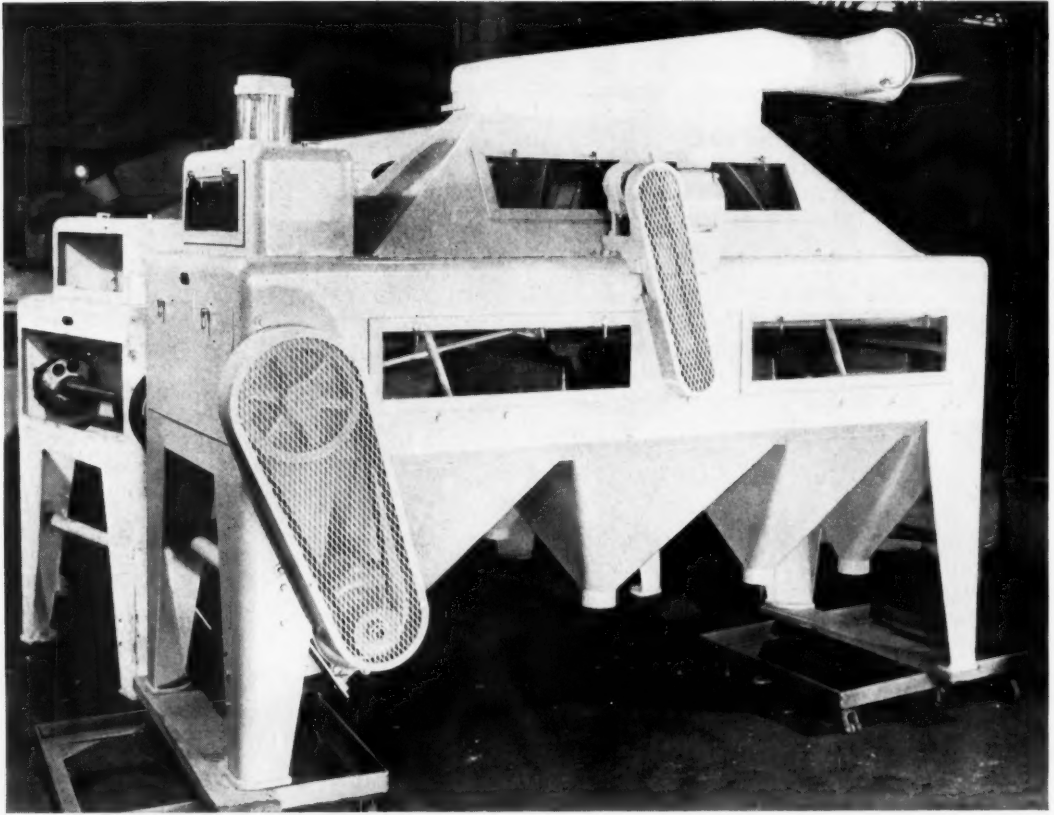
LUBRICATION IN THE MILL

The various devices which have been assembled



Courtesy of Allis-Chalmers Mfg. Co.

Figure 6—A group of Nordyke straight line roller mills.



Courtesy of Allis-Chalmers Mfg. Co.

Figure 7—Driving side of an Allis-Chalmers metal flour purifier. Note the individual motor drives. The use of heavy duty anti-friction bearings insures a uniformly positive motion to the sieve.

for the mechanical handling of grains to the elevators are incident only to storage, the grain elevators serving as receiving containers, so to speak, to hold the grains until they go to the mills for grinding to flour, cornmeal, or processing into cereal foodstuffs.

The flour mill takes probably the majority of all grains harvested and has perhaps the most interesting assembly of machinery from a lubrication point of view. The object of milling is to produce flour. Wheat is the principal raw material although corn, rye, buckwheat and oats also are ground for food purposes but not always as finely as flour.

The Process As a Whole

There are three principal divisions in flour milling today:

- a. Cleaning and preparation of the wheat.
- b. Grinding.
- c. Sifting or dressing of the ground products.

In a modern mill all of the equipment necessary for complete operation is combined to form a single

unit although there may be a number of such complete units in one mill. No part of the process is operated independently of any other; the grain after being fed in at the cleaning screens, passes on through the mill and into the flour bins without stopping enroute. On account of operating as a unit all the equipment is usually tied together or connected up to the same power source, operating as a single machine of many parts.

Cleaning is necessary to remove all dirt, smut and to separate foreign seeds. Tempering is necessary to develop a moisture content suitable for milling. Then the grain goes to the first breaker rolls. The break system consists of four to six distinct operations, each having its own means of separation. In adjusting the breaker rolls the main objective is to produce as large a percentage of middlings as possible, with a minimum percentage of flour. It is also desirable to free the bran of all adhering flour and at the same time producing a broad bran. The first three breaks produce the middlings from which the patent flour is made while from the fourth and fifth breaks middlings of a lower quality are ob-

LUBRICATION

tained, which are used for second grade of flour. A shearing action is obtained between each pair of breaker rolls due to corrugations which are cut with a slightly longitudinal spiral and by running one roll faster than the other.

Each series or group of reduction rolls is set up closer, so that each produces a finer product. The middlings, from each grinding process, are passed to the sifters or bolting machines, where such flour as has been made is separated out, and the tailings, after the impurities have been removed, pass to the next mill for further grinding. The tailings from the last mill are used in coarse flour or stock feed, being usually sent to a shorts duster of either horizontal or vertical type.

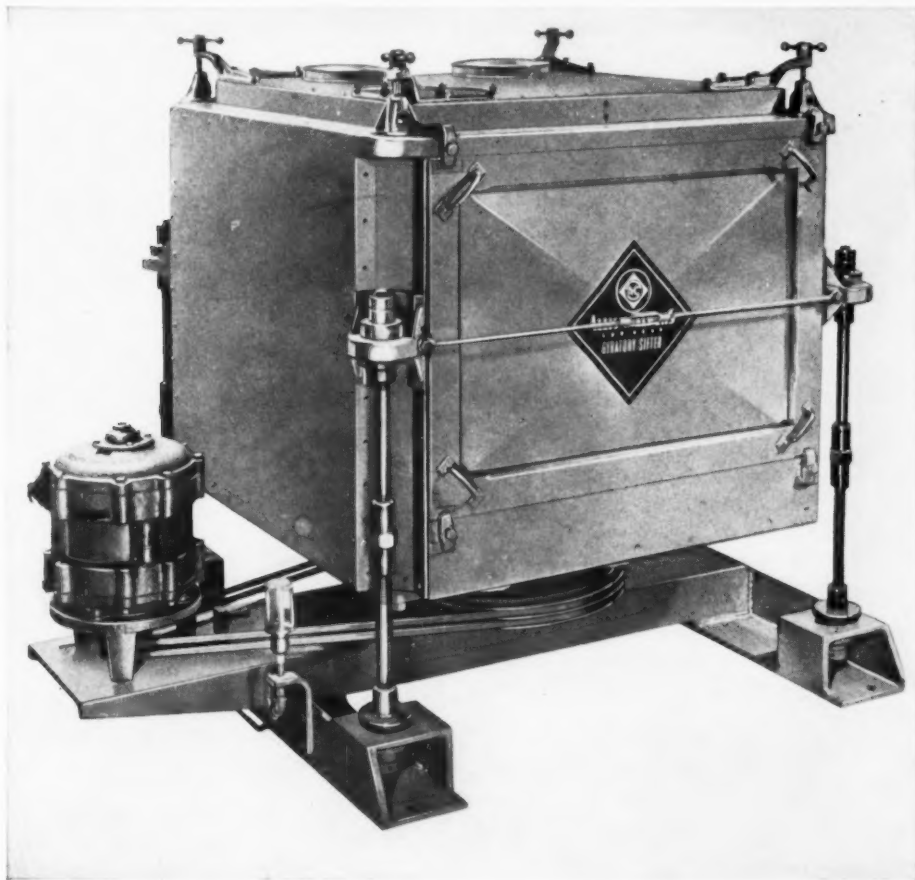
Cleaning Machinery

During the cleaning procedure grain goes over cleaning screens, scourers, brush polishers and through the tempering process. The shaking screen

predominates in the first treatment, the grain passing over flat screens mounted at an angle so that as the machine is vibrated the grain travels down the screen. In the flour mill the mesh is designed to permit the passage of the wheat grains alone, excluding foreign grains, straws, etc.

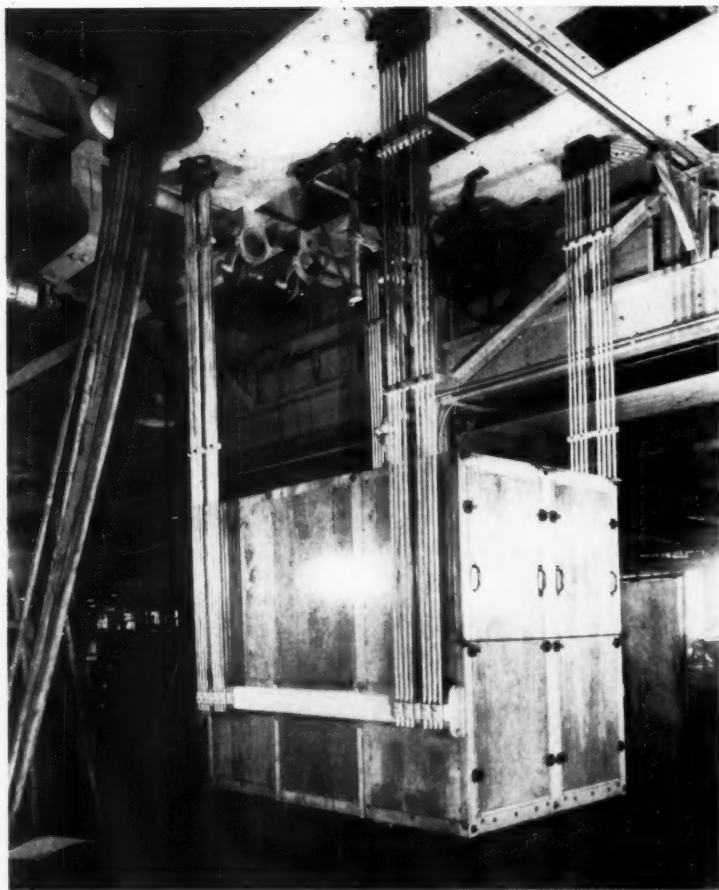
The vibratory motion of the screens is brought about by eccentrics, operated at speeds up to 550 rpm, the shock of reversal being partly taken up by suitable springs. The bearings and eccentrics may run warm on certain types of screens, especially if there is too much freedom of motion. The lubricant should therefore be selected with this thought in mind, planning on a viscosity which will be ample to take up the shock loads.

Scourers and brush polishers clean the grain further, then a pre-break roll treatment with strong air suction on the stream after it has been cracked open, is given to remove all crease dirt. Such machines may be vertical or horizontal. In either type the cen-



Courtesy of Allis-Chalmers Mfg. Co.

Figure 8—An Allis-Chalmers low-head gyratory sifter. In this machine the upper anti-friction bearing is grease lubricated; an oil pipe conducts oil from the oil pot to the lower bearing. Centrifugal force keeps the oil circulating through the bearing.



Courtesy of Allis-Chalmers Mfg. Co.

Figure 9—An Allis-Chalmers free swinging sifter.

tral shaft with scouring cylinder or scrubbing brushes is the moving element. Speed of operation is as high as 700 rpm in machines of small capacity, and as low as 350 rpm in the larger sizes. The lubrication demands are met by an N.L.G.I. No. 2 grade of grease or a medium viscosity machine oil, according to bearing design.

There are no mechanical features in tempering to present lubrication problems. The grain is usually moisturized by hot water during passage through conveyors which provide for thorough mixture. The moisture content, and temperature of the grain are very carefully checked and regulated as they affect materially proper grinding later on.

Grinding and Milling Machinery

The rolls used for grinding or milling are very accurately made and carefully adjusted as they constitute the most important part of the mill from a lubrication viewpoint. They must be exactly parallel at all times so that the grain in passing through them

will be subject to the same clearance along the entire length of the rolls. Because of heat generated by the grinding action of the mill and at the bearings, it is customary in grinding the surfaces to taper the rolls about an inch back from the ends a few thousandths in diameter in order to compensate for expansion and prevent actual contact at the ends when grinding.

One of the rolls is fixed in position, except as to provision for vertical adjustment to effect paralleling; the other is adjustable through springs to provide even clearance and pressures as desired. The springs keep the rolls from contact and also furnish a shock absorbing element should any hard foreign substance be fed in with the grain.

Inasmuch as one roll travels faster than another in ratio varying from 1 to $2\frac{1}{2}$, to 1 to $1\frac{1}{4}$ (or 1 to 1 in pre-break systems), a differential speed is provided through gears, chains or belts from the jack shaft on the mill. The speed ratios desired determine the size of the gears or sprockets to be used. In designing, the machines are generally built as double units, or as two pairs of rolls in one

frame mounting, being actuated from the same jack shaft.

In the more modern mills the rolls are mounted on ring oiled plain babbitted bearings. In the older machines, however, the fixed collar type of bearing prevails, the collar on the shaft or roll neck dipping into an oil reservoir to carry up oil for distribution to the bearing. This collar helps to restrict the lateral motion of the roll.

In addition to the comparatively high pressures involved, the lubrication engineer must consider the speed of around 500 rpm when selecting the roll bearing lubricant. If oil is required it must be heavy enough to maintain a film which will withstand the pressure imposed without danger of boundary lubrication; at the same time it must not develop too much fluid friction under the speeds involved, otherwise bearing temperatures might rise to add to the heat developed during grinding. For this reason, heat control is maintained by radiation and ventilating the rolls and bearings.

Sifting Machinery

From the breaking rolls the break stock goes to the sifters for separation, the tailings therefrom passing to the next finer set of rolls.

Sifters may be of different types; a widely used form is a large box-like arrangement suspended from ceiling beams or upper supports on long wood or steel rods of from $\frac{3}{4}$ " to $\frac{7}{8}$ " in diameter, termed reeds. Two, four or six of these box-like sifters are usually grouped around a central vertical shaft to which they are connected, and from which they receive a gyratory action through offset spindles. The shaft turns at a speed according to the circle. For re-bolting and special jobs the speed is usually 265 rpm making a $2\frac{1}{2}$ " circle. Some $11\frac{1}{2}$ " circle machines turn at 345 rpm. It is mounted on a step bearing which carries the weight of the shaft and pulleys.

While a good quality, medium bodied machine oil will effectively lubricate some step bearings, when grease is required it must of necessity be resistant to throw-off and should have a fairly high-melting point to insure continuous lubrication. Normally, these bearings are lubricated through remote grease fittings or compression cups at intermittent intervals and the grease used must provide adequate lubrication for the period otherwise excessive heating and wear will occur.

The break sections scalp or discharge their product to purifiers built somewhat on the principle of the cleaning screens, except that much finer mesh material is used. Here the various middlings are separated so that they may be delivered to suitable rolls for finishing grinding. These screens are mounted horizontally but slightly pitched, so that the material being fed at one end will gradually work down to the other as vibration occurs; at the same time a suction is created above to carry off the bran which is lighter and of greater surface area. The middlings are sifted through, and the tailings are returned to mills for further grinding. The action of the screens is

effected through eccentrics connected to a small belt-driven shaft on the end of the machine. The same machine oil as used on the step bearing (mentioned above) also can be used here.

Bran Machinery

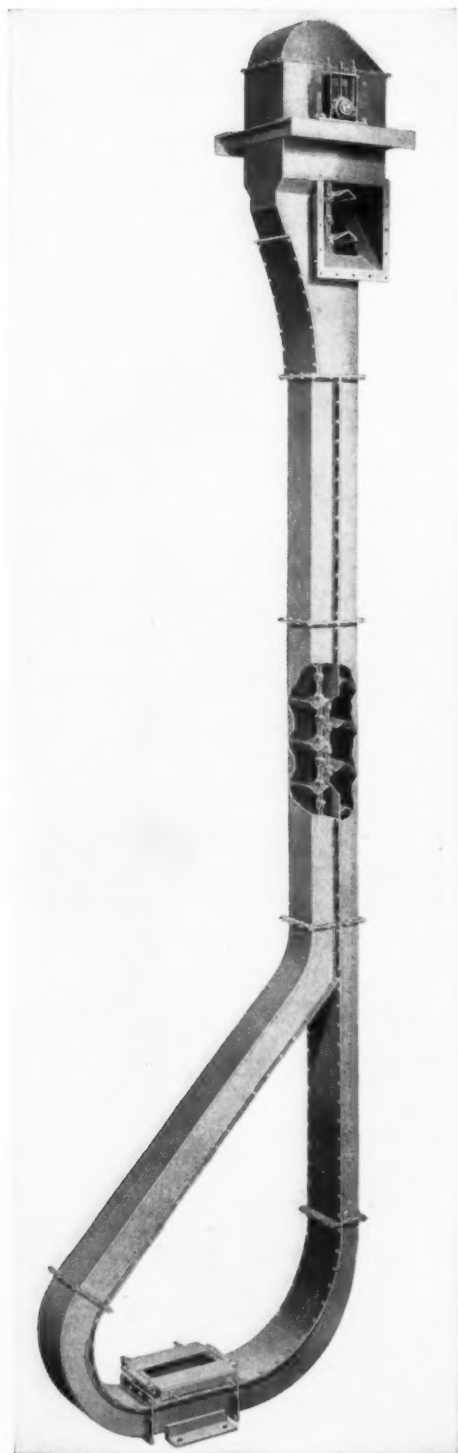
Bran is probably the chief by-product produced in the manufacture of flour. It is passed through bran dusters which remove any adhering endosperm. A bran duster can be horizontal or vertical. The latter contains a vertical cylinder of cloth on a frame which revolves slowly inside the housing. The bran is spouted in at the top, and by means of a revolving disk is distributed over this cloth (or case). Brushes which are attached to the central spindle revolve at 300 to 450 rpm; they dust off the particles of bran. Flour is discharged at the bottom through a suitable opening.

The lower head of the case revolves in a bab-



Courtesy of Allis-Chalmers Mfg. Co.

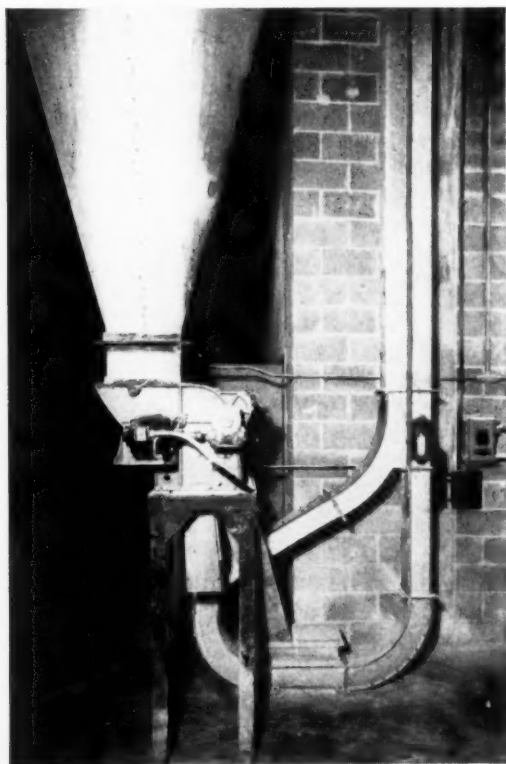
Figure 10—An Allis-Chalmers Reliance shorts duster.



Courtesy of Link-Belt Company

Figure 11—A Link-Belt Bulko-Flo conveyor of the loop-loading type showing interior details.

bitted, oil-retaining bearing. The spindle which carries the brushes is mounted on a step bearing at the bottom, and is usually equipped with a self-oiling bearing at the top. The driving belt is passed over a pulley on the spindle shaft just above its step bearing outside the housing. Slower motion is imparted to the case by means of encased gears or a small short-centered belt.



Courtesy of Link-Belt Company

Figure 12—The foot of a Link-Belt Loop-Loading Bulk-Flo elevator, 62 ft. high overall, for handling flour.

CONCLUSION

The handling of grain from the time it is received at the elevator to the time the flour or finished cereals are packaged for the market — is a fascinating procedure. It interests the mill management who are responsible for production at the lowest possible cost. It interests the materials handling engineer because it involves production-line conveying methods. It interests the fire prevention and insurance people because static electricity may cause dust explosions if temperatures and ventilation are not properly controlled. It interests the lubrication engineer because he, along with the maintenance people must keep the conveyors running efficiently and the mill roll drives, and other mechanism bearings properly lubricated at all times regardless of the weather.

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TEXACO RECOMMENDATIONS **FOR GRAIN HANDLING AND FLOUR MILLING MACHINERY**

Power Plant

STEAM TURBINES — According to make and Texaco Lubrication Chart	Texaco Regal Oils (R&O)
WATER WHEELS	Texaco Regal Oils (R&O)
STEAM CYLINDERS	Texaco Pinnacle Cylinder Oil
DIESELS	Texaco Ursa Oils
AIR COMPRESSORS — Crankcase and Air Cylinders	Texaco Alcaid Oil
MOTORS — Ring Oiled	Texaco Alcaid Oil
Grease Lubricated	Texaco Regal Starfak No. 2

Power Transmission Units

ELECTRIC MOTORS — Ring Oiled	Texaco Cetus Oil or Alcaid Oil
Anti-friction Bearings	Texaco Regal Starfak No. 2
GEAR — MOTORS — Cold Weather Service	{ Texaco Regal Oil E (R&O) or Algol Oil
Warm Weather	{ Texaco Regal Oil F (R&O); G (R&O) or Ursa Oil
REDUCTION GEARS — According to type and temperature	{ Texaco Meropa Lubricant 1, 3 or 6
CHAIN DRIVES — According to temperature	Texaco Algol or Ursa Oil
BEARINGS (General)	
Oil Lubricated — In cold weather	Texaco Cetus Oil
In warm weather or on large slow moving units	Texaco Alcaid or Algol Oil
Grease Lubricated	Texaco Starfak Grease M

Conveyors, Blowers and Fans

BEARINGS — Oil lubricated, according to temperature	Texaco Cetus or Alcaid Oil
Grease lubricated	Texaco Starfak Grease M

Mill Machinery

SCREENS

ROLLING MILLS

SIFTERS

REELS

BEARINGS

Ring-oiled or waste-packed	Texaco Cetus or Alcaid Oil
Collar — oiled type	Texaco 655 Oil
Grease lubricated	Texaco Starfak Grease M

GEARING	{ Texaco Meropa Lubricants 3 or 6
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FLOUR DRESSERS — Sifter eccentrics	{ Texaco No. 919 Lubricant or Texaco Marfak
--	--

PELLET MILLS — Grease lubricated — anti-friction bearings	Texaco Marfak No. 1
Gears	{ Texaco Meropa Lubricants 3 or 6

BAG SEWING MACHINES	Texaco White Needle Oil B
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Note 1: The above recommendations are made taking into consideration average operating conditions. Where unusual service is involved or under extended periods of very cold weather, it is advisable to consult a Texaco Lubrication Engineer.

Note 2: For grease lubricated anti-friction bearings, Texaco Regal Starfak No. 2 is preferred. For plain bearings, Texaco Starfak Grease M is usually recommended; it may also be used as an anti-friction bearing lubricant.

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anti-friction
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Texaco Regal
Starfak

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Number 3

Lubrication

A Technical Publication Devoted to
the Selection and Use of Lubricants

THIS ISSUE

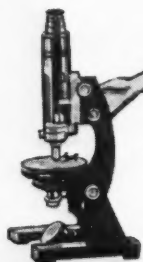
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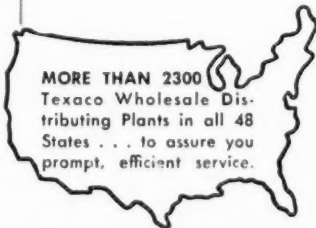
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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by

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A Million Miles of Car Testing in the Laboratory

MANY oil companies have installed chassis dynamometers varying appreciably in cost and design for examining the fuel and lubrication requirements of various automobiles as well as their performance with various fuels and lubricants.

The chassis dynamometer described herein is unique in its mechanical simplicity, and has proven to be sufficiently rugged to have carried out over 1,000,000 miles of car testing with almost no service difficulties.

One of the first installations of apparatus on which an automobile could be run indoors under load in this country, was made about 1907 by the Automobile Club of America in New York City. Later this equipment was transferred to Yale University, and was described in 1915¹; a second report of data obtained was published in 1922². Full credit

is hereby given to this installation as the inspiration for our design, and to data supplied by Professor E. H. Lockwood as a basis for the quantitative

¹"A Versatile Car Testing Dynamometer with Mechanically Driven Fan Load" by Neil MacCull, Cons. Engr.—The Texas Company.

design to accommodate average cars of that period. The principal original feature of this installation was the incorporation of a large fan, driven indirectly by the car through the traction wheels, and serving

the dual purpose of simulating the air resistance and cooling of cars on the road. Schematic diagrams of this layout have been published from time³ to time⁴, but information on the basis of design has only recently been published. The comparative simplicity of the installation and its apparent satisfactory correlation with road performance have been noteworthy.

Figure 1 indicates the schematic arrangement. It will be seen that the rear wheels of the test car rest on large traction wheels carried by a truck axle. The propeller shaft of this axle drives through a gear box and an electric generator to a second axle which is belted to the fan. The drive

ratios used in this drive system are such that the air discharge velocity from the fan equals the car speed approximately. The fan size has been selected so that the power required to drive it may be made equal to the power required to overcome the car air

THE power required at the rear wheels of a car to drive it at a given speed on a level road may be broken down into two main components:

1. Air resistance, and
2. Front wheel rolling resistance.

If these two factors can be reproduced by the loading system of a chassis dynamometer, cars tested thereon will reveal the same performance as on the road. Examination of the two components listed above indicated that this can be accomplished by simple means.

This issue of Lubrication is therefore devoted to a description of the application of these principles to new car performance testing for the ultimate benefit of the consuming public in better fuels and lubricants. The particular chassis dynamometer described is located at the Beacon Laboratories of The Texas Company, where work of this nature has been continually in progress for 17 years, i.e., since the founding of these Laboratories.

A detailed description of this design was presented in a paper before the Society of Automotive Engineers* this month to which readers are referred if they desire more information than is given here.

resistance by adjustment of the outlet area of the fan nozzle.

Additional power absorption, equivalent to car friction, or hill climbing, is accomplished by the electric generator. Measurement of the power absorption by both fan and generator, is made by the torque reaction of the housing of the axle which supports the traction wheels in the same manner as is customary with conventional cradle dynamometers. To this end, the axle housing is "cradled" on ball bearings in which it is prevented from rotating by a torque arm and linkage to a scale system. This scale system is calibrated to read in pounds of draw bar pull or traction as is customary in railroad terminology.

This schematic shows that air may be drawn into the fan plenum chamber directly from outside and discharged through the entrance door, or any desired proportion may be recycled to the fan plenum chamber through the grating and under the floor by manipulation of suitable dampers. It is thus possible during winter weather, especially during nights, to test cars at low temperatures without the use of refrigeration equipment. On the other hand, any desired degree of heat may be used, by recycling the air and using unit heaters in the return air path. Exhaust gases are of course carried away by flexible connections to an exhaust duct provided for the purpose.

The car is held in position by the simple means of front wheel chocks, which have proven adequate. By pinning these chocks in a series of holes in the floor plates, adjustment may be made to center the rear wheels over the traction wheels. Protection from tire blowouts has been made by saddles under the axle with a clearance of about an inch, to prevent rim contact on the traction wheels. Removable wire guards are inserted in the floor plates just clear of the rear wheel fenders, as shown in the photograph of Figure 2. These were devised to confine a thrown tire in case of a blowout, although blowouts are rare when precautions are taken to assure running with full rated air pressure in the tires.

To facilitate operation of the loading equipment from the driver's seat in a car, a swinging panel is provided which gives the driver access to the necessary controls. The traction scale is located near the left front wheel so that it too can be read from the driver's seat.

The location of weighing scales to measure the weight on each wheel as a car is rolled into position for testing, has been found convenient.

This gives a brief description of the general layout. A detailed description of the engineering of the various important parts follows.

GENERAL CONSIDERATIONS

The *air resistance* of a car varies approximately as the square of the car speed — so does the load on a centrifugal fan. By suitable selection of the ca-

capacity of such a fan, it may be mechanically coupled to the drive wheels of a chassis dynamometer so as to absorb the same power as the air resistance of a car on the road at all car speeds. Furthermore, the air discharge from this fan has sufficient volume to provide an excellent means of cooling the car radiator and underparts. By suitable choice of fan size, nozzle area and drive ratio between the drive wheels and fan, it is possible to obtain the same air velocity as the car speed, while absorbing the same power which would be required to overcome air resistance on the road. Such a relationship would hold for all car speeds, since centrifugal fan characteristics are such that the discharge velocity varies directly with speed and its torque as the square of the speed. Assuming that the fan is correctly selected for this use, adjustment of the outlet *nozzle area* will result in varying the power absorbed at a given car speed, over the moderate range of $\pm 25\%$ necessary to accommodate the individual characteristics of normal cars, without appreciable change in air velocity. This will be amplified later.

The front wheel rolling resistance is controlled almost entirely by the tire resistance, which for average cars may be approximated by straight line from a value of about 18 to 25 lbs. at zero speed to 30 to 40 lbs. at 60 miles per hour. Experience shows that friction of the transmission system between the drive wheels and the fan, with its many bearings, grease seals and commutator brush friction, totals a little less than the front wheel friction of average cars. It is therefore desirable to supplement this friction by a suitably controlled electric load in order to obtain a reasonable equivalent of front wheel friction.

The requirements discussed above may be reviewed by the aid of Figure 3. The band C-D represents the front wheel resistance; the curve B-W represents the air resistance, and the sum of the two, curve C-A, is the traction required at the rear wheels of the car. At the time of design of our first chassis dynamometer, 1929, the best available data indicated that the traction at point A should be 200 lbs. at 60 miles an hour, being made up of an air resistance of 163 lbs. and a tire resistance of 37 lbs. Calibration procedure has been to adjust the fan nozzle area so as to develop this value at this speed.

Since the chassis dynamometer friction has proven inadequate to simulate the front wheel friction of cars, the resulting load at low speeds has been too low, and it has become customary to apply electric loads at low speeds to reproduce manifold vacuums determined on the road. A constant voltage regulator such as a thyatron or amplidyne circuit may be used to maintain a substantially constant output current from the generator to a resistance load to simulate front wheel friction. Calibration, therefore, consists of two steps: 1st, setting the voltage regulator so as to develop the desired "zero" speed

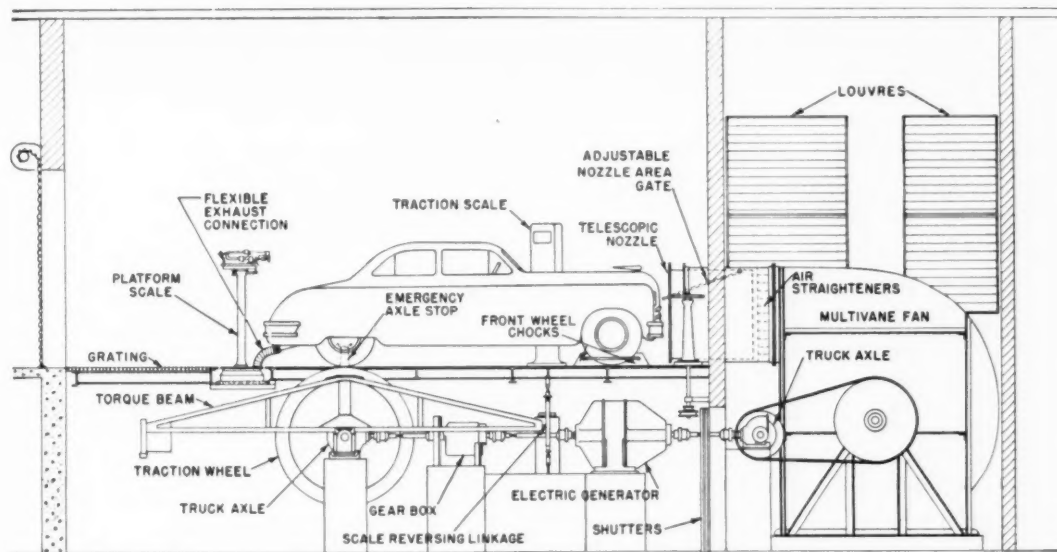


Figure 1 — Schematic drawing of The Texas Company chassis dynamometer.

traction reading when motoring the chassis at about 1 mile an hour, and 2nd, adjusting the fan outlet area at 60 miles an hour until the desired traction is obtained at this speed.

The latest data available indicates that curve C-A for average 1946 and 1947 cars should fall between 22 lbs. at zero speed and 160 lbs. at 60 miles an hour. Obviously adjustment for each car tested may be made if desired, using measured front wheel friction to set the electric load for zero speed — and manifold vacuum obtained on the road or preferably the actual air resistance at 60 miles an hour for setting the fan nozzle area. However, unless the resistance of air and front wheels at 60 miles an hour is obtained by unusually precise tests, it will not be in keeping with the degree of accuracy obtainable from chassis dynamometer data. Since a valuable asset of the chassis dynamometer is the ability to reproduce runs under identical conditions over long periods of time, calibration may be set for *average* cars and not altered for individual cars on routine test. The discrepancies thereby introduced will ordinarily be less than the errors of determining the values of individual car resistances on the road. Furthermore, individual car values may vary more from the average of the same make than from the carefully determined average for all cars.

AIR RESISTANCE

From the foregoing it becomes apparent that considerable study is warranted on methods of measuring the air resistance of cars, since it is the basis of all chassis dynamometer tests.

There are three methods in general use for determining the air resistance of automobiles: wind tun-

nels, coasting down a hill, and deceleration on a level grade.

While the first was used by the Kansas State Agricultural College for moderate air speeds, the required wind tunnel for air speeds compatible with top road speeds of today would be too costly for most installations. There is also some question as to the effect of motion between the car underparts and the road, which is lacking in wind tunnel tests. This is particularly true of tests on automobile models.⁵

The coasting method consists of determining the steady speed at which a car coasts down a known gradient in neutral gear or with open clutch. To obtain this steady speed a long hill of uniform grade is desirable, and several runs are required, each starting at the maximum speed obtained on the previous run, until no acceleration develops. Such runs should be made when the wind is almost nil. The force causing car movement is the total weight of car, crew, equipment, etc., multiplied by the sine of the gradient angle which for hills normally used, is closely equal to the gradient in percent. This force equals the air resistance plus the rolling resistance of all wheels. When these rolling resistances are measured on the chassis dynamometer, they may be subtracted from the total car resistance, leaving the net wind resistance. Sometimes, where hills are available to provide two different gradients, data may be obtained to solve simultaneous equations incorporating the two variables of air and rolling resistance without recourse to friction data from the dynamometer.

In those parts of the country where suitable hills are not available for the coasting method, the de-

celeration method is generally used. This consists of measuring the rate at which a car loses speed from some speed such as 70 or 80 miles an hour, when slowing down in neutral gear on a level road without use of the brakes. Since accurate car speeds are needed at known time intervals, special instrumentation is usually provided by means of a "fifth wheel," such as shown in Figure 4, which makes electrical impulses, at each revolution, which are recorded simultaneously on a chart with a pen trace from a tuning fork. Analysis of these charts is much more of a task than the simple computation for the coasting method. It is customary to run such tests in alternate directions to average any deviation from the desired zero grade, and then average at least 5 pairs of consistent runs. This method also requires such tests be run in still air, since the effect of wind cannot be eliminated by averaging runs in opposite directions. This is because air resistance is a function of the square of the air speed. The error from ignoring wind always results in a higher value for air resistance than it should be, and becomes of greater relative magnitude at lower car speeds. For instance, a 10 mile an hour head wind averaged in both directions, will give an air resistance 25% high at 20 miles an hour, 6% high at 40, and 3% high at 60. Thus the advantage of making such runs just after dawn on calm days.

These three methods have been used at various times to collect air resistances of cars, and the results of typical tests over the past 20 years are of sufficient interest to be summarized here.

In 1927 the Kansas State Agricultural College issued a Bulletin (No. 18) on the "Atmospheric Resistance of Motor Vehicles." The data in this report were developed in a wind tunnel 12 feet wide and 9 feet 8 inches high, the top wind speed being limited to about 35 miles an hour because

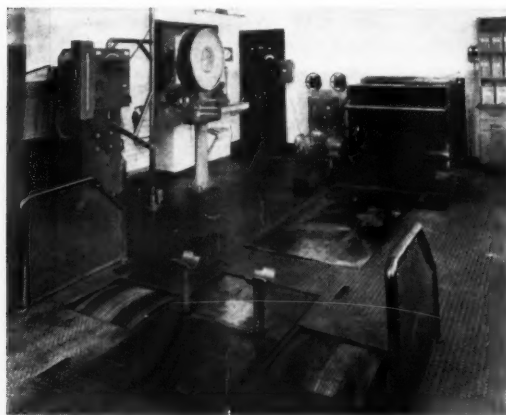


Figure 2 — View of chassis dynamometer showing removable wheel guards, and adjustable saddles to support car axle in case of a tire blowout. The swinging control panel, traction scale and adjustable gate in the telescopic fan outlet nozzle are shown also.

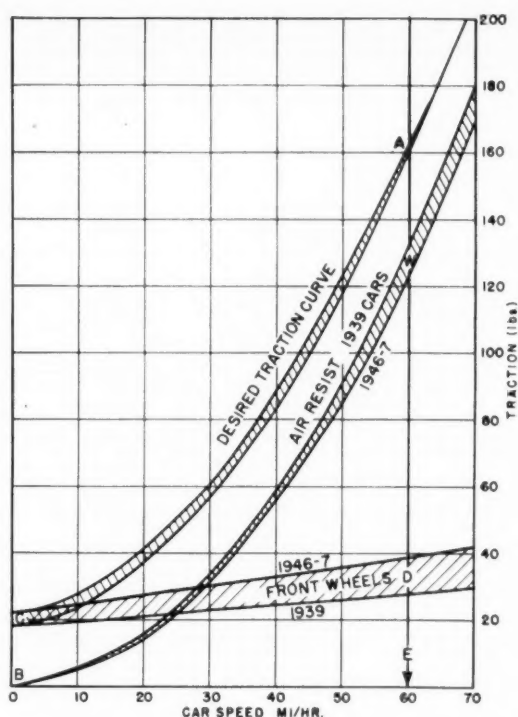


Figure 3 — Desired dynamometer traction curve for level road operation of average cars. Values of front wheel and air resistances are shown also.

only about 200 horsepower was available to drive the wind generating propeller.

A supplemental report (Bulletin No. 33) listed data on 55 cars of 14 makes from 1925 to 1933. By use of an airplane engine to drive the wind tunnel fan, air speeds up to 50 miles per hour were obtained. The average air resistance was equivalent to 175 pounds at 60 miles per hour. In this bulletin a check method was described where cars were coasted down hills of various gradients. The data obtained by this method averaged within 2 per cent of the values obtained on the same car in the wind tunnel.

Yale University has for many years obtained the air resistance of cars for their chassis dynamometer tests by the coasting method, which they use in preference to deceleration methods. While they prefer testing on two different gradients, results on only one hill are satisfactory when rolling friction is measured on the chassis dynamometer.

The average data of 13 sedans tested by the coasting method in 1928, on a single hill of 4.78 per cent gradient, indicated an air resistance of 163 pounds at 60 miles per hour. It was on the basis of such data, supplied through the courtesy of Professor E. H. Lockwood, that the calibration of our first chassis dynamometer was based.

In a very interesting study by Professor W. E. Lay⁸, of the University of Michigan, he has dis-

cussed the deceleration and coasting methods of determining air resistance and indicated his preference for the latter. He also described an additional method in which the whole car body was "floated" on the chassis so that the air resistance could be measured directly by a spring scale attached to the frame. For obvious practical reasons this method is not applicable to automobiles as marketed, as it requires a special body construction and mounting. For simplicity and academic reasons, the body construction was a straight sided box entirely enclosing a conventional chassis, but with all corners and edges broken to a 9 inch radius. In spite of the large frontal area of 33.2 sq. ft., the air resistance at 60 miles an hour was only 123 pounds. Thus this almost unstreamlined body, with about 20 per cent greater frontal area than conventional cars of that period, had an air resistance only about 75 per cent as great! This unexpected result was checked by the deceleration method at the General Motors Proving Ground.

The first study of car resistance by The Texas Company was made about ten years later than the data supplied by Professor Lockwood. Tests were run by both the coasting and deceleration methods. This preliminary work indicated that the air resistance averaged 122 pounds at 60 miles an hour by the deceleration method and 143 pounds by the coasting method.

Another study of car wind resistance by this company was made in 1948 by the deceleration method. The wind resistance at 60 miles an hour was found to be about 124 pounds.

Summarizing these values of air resistance obtained at various periods, the table on page 31 shows the decreasing air resistance with the modernization of design.

It appears that but little reduction in air resistance per square foot of frontal area has resulted

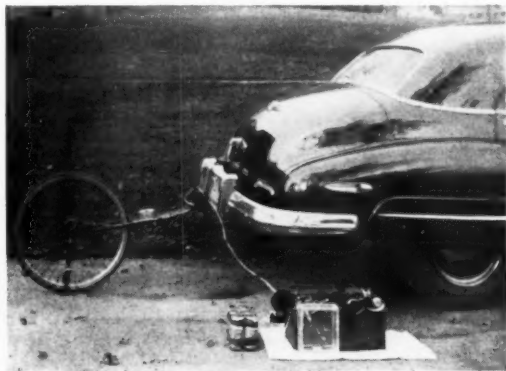


Figure 4 — The "Fifth Wheel" attached to the rear bumper of a car, for accurate indications of distance traveled. The additional instrumentation which must be carried in the car, including a chart recorder; and tuning fork for recording known time intervals, etc., is shown in the foreground.

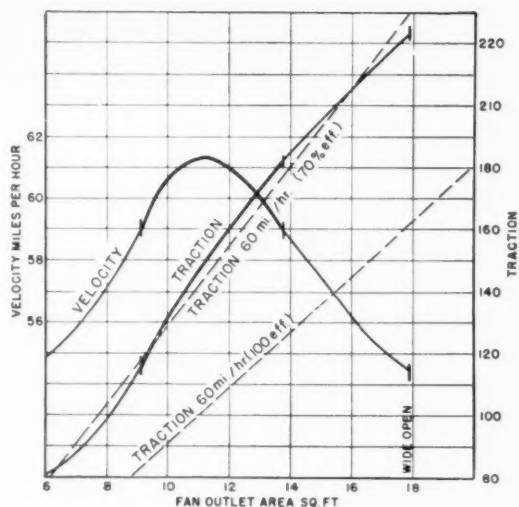


Figure 5 — Characteristics of the chassis dynamometer fan, showing the adjustment of traction load possible by changes in outlet area, with only a small variation of air speed. This is a No. 14 multivane fan, running at 234 rpm for a nominal 60 mile an hour air speed.

from the style "streamlining" since 1928, and even 1947 cars still have a higher unit air resistance than the rectangular box-car of Professor Lay. The reduction of almost 30 per cent in air resistance during this period is largely due to a 20 per cent reduction of frontal area, most of which has been taken from between the car and the road, that is, the cars are built closer to the ground.

PRINCIPLES OF BLOWER SELECTION

Calculations of blower performance may be made at any convenient speed, which in this case is taken at 60 miles an hour. A type of blower is selected with a characteristic such that the total pressure reaches a peak near the air volume giving maximum efficiency, and the design operating point should be at or near this peak. A curve for such a fan is plotted in Figure 5, showing air velocity and traction load* as they vary with fan nozzle area, for a size 14 Multivane fan at 234 rpm. The heavy parts of the curves represent the range of traction values over which the air velocity varies only about ± 1 mile an hour from the desired 60 mph. The desirability of locating the total pressure peak near the main operating point becomes evident. The range of satisfactory operation for this fan is thus at least from 115 to 182 lbs. traction. When a 3 mile an hour drop in air speed (5%) can be tolerated, it becomes extended to about 100 lbs. on the low side, and 200 lbs. on the high side.

The traction curve approximates a straight line, which it would be if the fan efficiency and air speed

*Traction (lbs.) = $\frac{375 \text{ H.P.}}{(\text{mi./hr.})}$

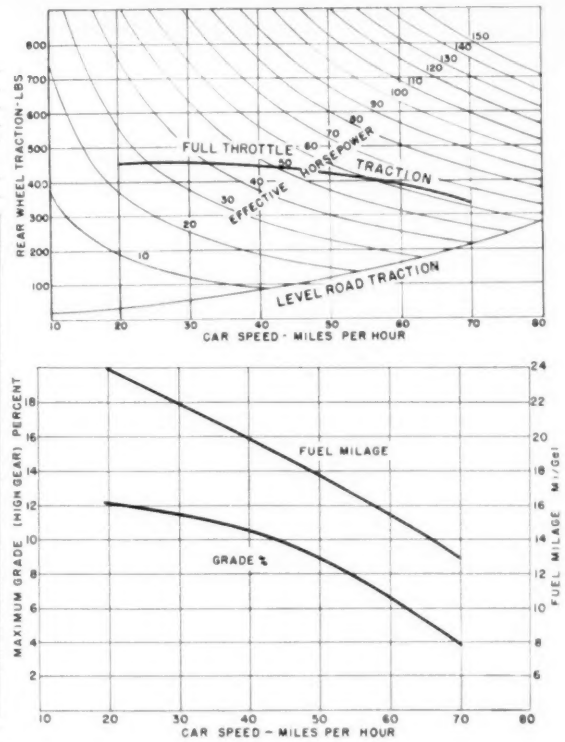
BEACON LABORATORIES
THE TEXAS COMPANY, BEACON, NEW YORK

THIS TEST RATES THE PERFORMANCE OF AN INDIVIDUAL CAR IN THE CONDITION IT WAS DELIVERED TO OUR LABORATORY. THE DATA MUST NOT BE CONSIDERED AS INDICATION OF THE MAXIMUM PERFORMANCE. A CAR OF THIS MAKE SHOULD EXHIBIT NO RESPONSIBILITY IS ASSUMED FOR VARIATIONS IN OBSERVATIONS WHICH MAY BE MADE IN REGARD TO THE PERFORMANCE OF THIS OR ANY OTHER CAR OF THE SAME MAKE.

1. MAKE & TYPE _____ VEHICLE NO. _____ ENGINE NO. _____
 2. CYLINDERS _____ HORSEPOWER _____ COMPRESSION RATIO _____
 3. DISPLACEMENT _____ CUBIC INCHES TYPE CYLINDER HEAD _____
 4. CAR WEIGHTS: FRONT _____ POUNDS, REAR _____ POUNDS, TOTAL _____ POUNDS.
 5. ENGINE REVOLUTIONS PER MINUTE _____
 6. ODOMETER: CAR AT START OF TEST _____ END OF TEST _____ TEST MILEAGE _____
 7. ODOMETER: CHASSIS DYNAMOMETER, START OF TEST _____ END _____ TEST MILEAGE _____

9. CAR SPEED (MILES PER HOUR)	20	30	40	50	60	70
10. SPEEDOMETER	20	30	41	52.7	64	75
11. AIR TEMPERATURE (°F.)	80	80	80	80	80	80
12. LEVEL ROAD TRACTION (LBS.)	52	58	64	68	100	100
13. FULL THROTTLE TRACTION (LBS.)	485	452	445	425	380	355
14. FULL THROTTLE - MAX. GRADE HIGH GEAR (%)	12.2	11.5	11.5	11.5	8.5	8.5
15. LEVEL ROAD FUEL ECONOMY (M.P.G.)	23.8	21.9	23.0	17.5	15.5	13.0
16. FULL THROTTLE FUEL ECONOMY (M.P.G.)	6.5	6.8	6.9	7.2	7.8	7.8
17. LEVEL ROAD MIXTURE RATIO (BRAIN/POUNDS)	15.1	15.5	15.1	15.0	15.2	15.1
18. FULL THROTTLE MIXTURE RATIO (BRAIN/POUNDS)	12.1	12.3	12.8	12.8	12.7	12.8
19. LEVEL ROAD WATER TEMP., IN (°F.)	141	147	153	162	170	186
20. LEVEL ROAD WATER TEMP., OUT (°F.)	155	158	163	168	170	186
21. LEVEL ROAD WATER TEMP., CYL. IN (°F.)	156	158	162	165	176	183
22. FULL THROTTLE WATER TEMP., IN (°F.)	195	195	192	192	191	188
23. FULL THROTTLE WATER TEMP., OUT (°F.)	208	205	203	202	203	196
24. FULL THROTTLE WATER TEMP., CYL. IN (°F.)	200	197	196	196	194	191
25. LEVEL ROAD EXHAUST MANIFOLD TEMP. (°F.)	521	675	605	591	1110	1280
26. FULL THROTTLE EXH. MANIFOLD TEMP. (°F.)	807	1030	1120	1175	1220	1207
27. LEVEL ROAD MANIFOLD VACUUM (INCH. HG.)	19.2	18.0	18.2	18.0	11.8	7.2
28. FULL THROTTLE MANIFOLD VACUUM (INCH. HG.)	0.3	0.4	1.0	1.8	2.1	2.8
29. LEVEL ROAD MIXTURE TEMPERATURE (°F.)	153	153	147	140	133	127
30. FULL THROTTLE MIXTURE TEMPERATURE (°F.)	148	143	136	131	123	123
31. CAR AND DYNAMOMETER FRICTION (LBS.)	180	170	184	197	210	236
32. COMPRESSION PRESSURE (LBS./SQUARE INCH)	145	149	156	161	159	155
33. LEVEL ROAD BACK PRESS., PSI	0.0	0.2	0.7	1.8	8.1	8.1
34. FULL THROTTLE BACK PRESS., PSI	3.5	2.8	6.5	8.8	8.7	10.5
35. ACCELERATION: EACH 2 SECONDS FROM 10 M.P.H. TO 30 M.P.H. (CORRECTED FOR CAR WEIGHT)	12.8					
36. FUEL USED (GALLONS PER HOUR)						

Figure 6 — First part of a typical chassis dynamometer data sheet with two sets of curves plotted from the data. Values shown are the average for a 1948 Chevrolet, Ford and Plymouth.



were constant along its length. A dotted straight line on Figure 5 shows the relation between traction and nozzle area of a 60 mi/hr. air stream at 100% fan efficiency*. A similar straight line is drawn for a 70% fan efficiency. These traction lines hold for any size fan, and since there is little difference in fan efficiency over a reasonable range of sizes of similar designs, the traction curve shown is a reasonable approximation for other sizes of fans. The principal effect of fan size is to move the air speed peak laterally, larger fans developing the peak at larger nozzle areas. The effect of fan size on the traction curve will be to shift the location of the bump which is the combined effect of the efficiency and air speed curves.

The fan outlet is provided with a set of "eggcrate" straighteners and with a telescopic section which permits testing of most cars with a given distance between the nozzle and the car radiator. This is considered to be desirable in making special radiator cooling tests. The outlet is 55 inches wide and adjustment of its area is obtained by a hinged gate

which varies the height of the air column from the floor, as indicated in Figure 1.

ROLLING RESISTANCE OF AUTOMOBILES

A study of rolling resistance shows that it is dominated by tire resistance⁶, and that the friction of ball or roller bearings normally makes up such a small part of the total that serious errors will not result even if they are neglected. For instance, typical cord tires have a rolling resistance which increases slowly from about 1% of the load carried at zero speed to about 1.6% at 60 miles an hour. However, the wheel bearings have a traction resistance of hardly 0.1%. Rear wheel resistance too is similarly dominated by tire resistance and though more bearings are involved in the power transmission system, only a few carry enough load to account for much friction unless lubricated with a heavy oil or grease which develops abnormal resistance at low temperatures. As an example of how small bearing resistance may be, it is of interest to note that the total resistance of freight train wheels and their plain bearings may be as low as 0.15% of the load carried, at very low speeds⁷.

*Traction (lbs.) = $\frac{\text{nozzle area (sq. ft.)} \times (\text{mi./hr.})^2}{400}$

LUBRICATION

FUEL SYSTEM TEMPERATURE DATA

	STEADY RUN AT 40 MPH 15 MIN.	1000 AFTER RUN				10 MPH 15 MIN.				40 MPH 15 MIN.			
		NO. MINUTES	FOUR MINUTES	ONE MINUTE	ONE MINUTE	NO. MINUTES	FOUR MINUTES	ONE MINUTE	ONE MINUTE	NO. MINUTES	FOUR MINUTES	ONE MINUTE	ONE MINUTE
1. AIR TEMPERATURE °F.	85	80	100	85	80	100	85	80	100	100	100	100	100
2. MAIN FUEL TEMP. °F.	100	101	118	88	90	117	88	90	117	118	118	118	118
3. FUEL PUMP INLET °F.	100	117	132	118	135	140	129	140	150	131	140	140	150
4. FUEL PUMP OUTLET °F.	100	124	137	120	140	153	138	147	158	137	151	157	161
5. CARBURETOR INLET °F.	111	127	144	135	155	164	146	150	167	140	158	163	173
6. CARBURETOR BODY °F.	113	131	145	120	137	151	128	143	153	140	140	151	180
7. MAIN FUEL JET °F.													
8. AIR UNDER HOOD °F.	110	131	140	130	155	162	144	146	158	139	156	160	173
9. FRONT MANIFOLD °F.	104	140	153	104	221	220	204	231	219	151	210	212	256
10. REAR MANIFOLD °F.	123	140	151	201	218	215	201	226	216	150	208	212	249
11. % OF FUEL SYSTEM													
12. PROBABLE POINT OF JAMMING													
13. FUEL DURING ACCELERATION													
14.													

LUBRICATION SYSTEM DATA

	20	30	40	50	60	70
1. SPEED (M.P.H.)						
2. AIR TEMPERATURE °F.	80	80	80	80	80	80
3. CRANKCASE OIL TOP °F.	208	218	225	238	245	257
4. CRANKCASE OIL BOTTOM °F.	197	207	216	225	231	244
5. CRANKCASE VENTILATION RATE (FT./MIN.)						
6. TEMPERATURE (CONVENTIONAL) °F.	147	162	168	173	176	177
7. TEMPERATURE (OVERHEAT) °F.						
8. REAR FUEL TEMPERATURE °F.	185	214	225	229	227	225
9. OIL PRESSURE (LBS./SQ. INCH)	23	25	27	29	31	31
10. OIL TO RECOMMENDED LEVEL						
11. OIL USED DURING TEST						

OIL CREAMING CHARACTERISTICS

	+10	0	+10
1. TEMPERATURE OF TEST °F.			
2. OIL VISCOSITY AT 210°F. (CENTISTOGES)			
3. OIL VISCOSITY AT 100°F. (CENTISTOGES)			
4. EXTRACTED TO TEST TEMPERATURE	10,000	5,000	5,000
5. BATTERY CHARACTERISTICS (VOLTS)	3.7	4.1	4.6
6. CREAMING SPEED (EXPLAN)	50.0	40.7	60.2
7. CREAM SETTING (EXPLAN)			
8. AIR/FUEL RATIO (LBS. AIR/LBS. FUEL)			
9. OIL USED DURING TEST			

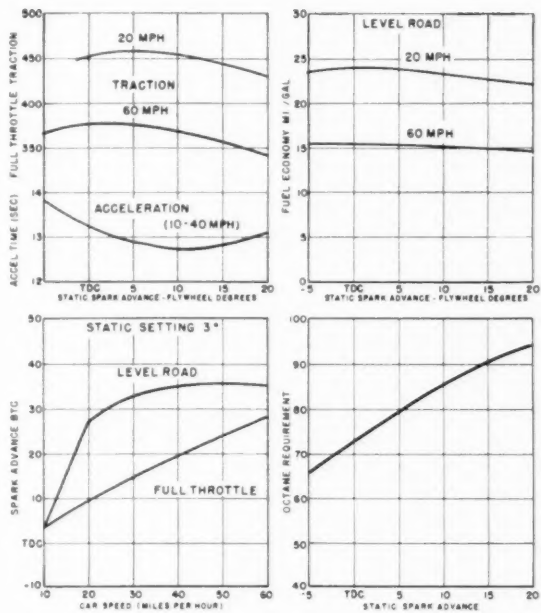


Figure 7 - Second part of data sheet of Figure 6.

Experience shows that the rolling resistances of the front and rear wheels of automobiles when extrapolated to zero speed, normally average about 1.1 and 1.3% respectively of the load carried. At 60 miles an hour, these values rise to about 2.0 and 2.4% respectively.

It will thus be seen that the make and condition of tires affect the rolling resistance of a given sized car more than features of conventional bearing design. Rolling resistance may therefore be approximated from a knowledge of tire characteristics, unless abnormal conditions exist such as bearings which are too tight, dragging brakes, too heavy

grease or too much of it, etc. In fact such approximations may come closer to the truth for the general run of any make of car than a test on a single unit.

Because of the dominance of tire resistance in controlling car rolling resistance, it is of interest to note the following tire characteristics. Tire resistance is mainly a matter of deflection from load, and tire construction, which determine the work done on the tire by deflection. Size has but little effect on tire resistance, since lower pressures are used on the larger tires (assuming a given load) for greater riding comfort. For any one tire, the inflation pressure, of course, has considerable effect because of its

AIR RESISTANCE OF AUTOMOBILES AT VARIOUS PERIODS

Source	Cars Tested			Avg. Frontal Area	Average Air Resistance at 60 mi./hr.		Test Method
	No.	Models	Date		per sq. ft.	area	
U. of Kansas Bulletin #18...	18	1917-1925	1927	27.8 sq. ft.	262 ^a lbs.	9.4	Wind Tunnel
U. of Kansas Bulletin #33...	56	1927-1933	1933	27.1	175 ^b lbs.	6.5	Wind Tunnel
Prof. Lockwood	13	1926-1928	1928	27.3	163	6.0	Coasting
Prof. Lay	1	"Boxcar"	1933	33.2	123	3.7	Direct
The Texas Company	5	1939	1939	23.9	143	6.0	Coasting
					116	5.1	Deceleration
					124	5.7	Deceleration
The Texas Company	7	1946-1947	1947	21.9			

^aExtrapolated from 40 mi./hr.

^bExtrapolated from 50 mi./hr.

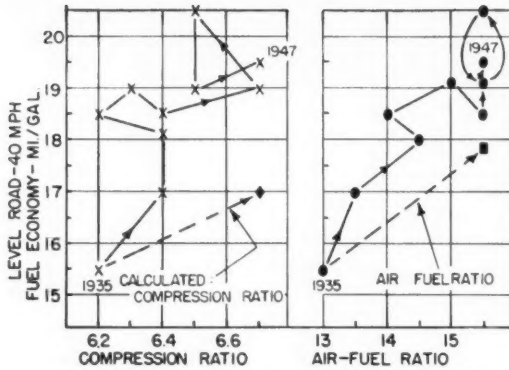


Figure 8 — Automobile engine trends since 1935.

control of deflection, and precautions should always be taken to maintain tires of cars on test at their rated pressure or higher. Use of only 50% of rated pressure may increase the tire rolling resistance by about 30%. Even a 5 pound drop may cause a 10% increase in the resistance and heat generation of average tires.

The construction of tires causes only moderate differences in resistance: 6-ply tires have about 5% higher resistance than 4-ply, and rayon cords have 5-10% less rolling resistance than cotton.

One of the most important variables in tire resistance is the load, with which it varies directly. Thus if a device is used to secure a car on the chassis dynamometer which can be tightened down so as to double the rear tire load, it will also double the rolling resistance and heat generated in the tire carcass.

Another important factor is the increased tire resistance caused by a small degree of front wheel

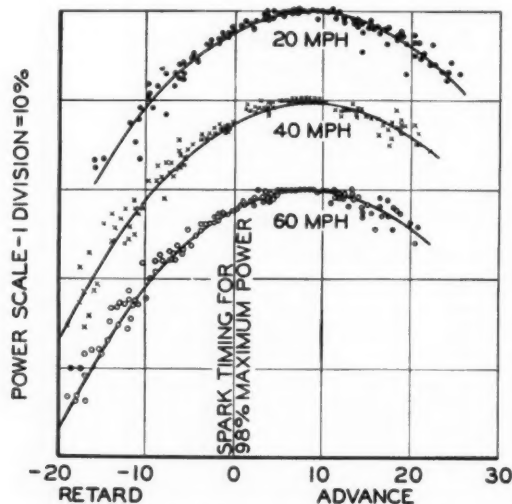


Figure 9 — Variation of engine output (in per cent), plotted against spark advance for 25 different cars, at several car speeds.

toe-in. Three degrees may cause over 100% increase. This becomes an important variable since toe-in may vary from car to car of a given make, either in manufacture or from service, so that it is unwise to assume from tests run on one car that others of the same design have the same rolling resistance.

HILL CLIMBING LOADS

When it is desired to operate a car on the dynamometer at a load greater than encountered on a level road, as when climbing a grade, the additional power is absorbed by the electric generator on the transmission shaft. For this installation a generator is used which is rated at 172 horsepower for continuous duty and 207 horsepower for one hour, both at 1750 rpm, which correspond to traction forces of

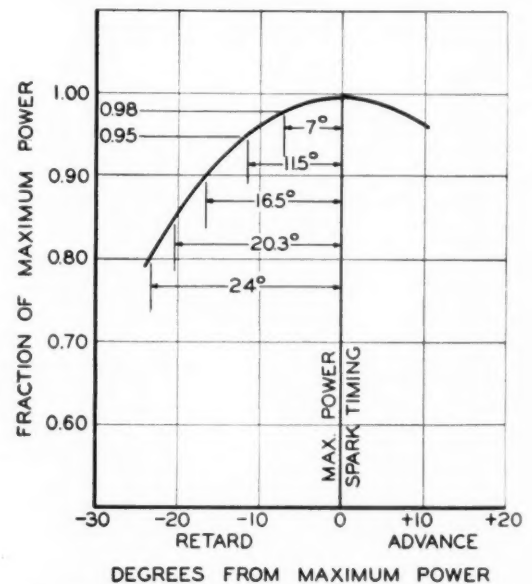


Figure 10 — Composite curve for effect of spark advance on per cent power developed for any conventional engine.

840 and 1001 lbs., respectively at 77 miles an hour. The maximum allowable speed is 2150 rpm which is reached at a car speed of about 95 miles an hour.

When it becomes necessary to use higher loads than the rated capacity of the direct connected generator, the gear box on the transmission shaft may be used. The present trend of automobile design toward automatic transmissions proves this feature to be of considerable assistance, at least in the low speed range where the car transmission is not in high gear. Most testing can be handled without use of greater gear reductions than third speed. In this gear, fan speeds and air velocities will be 76% higher than normal but this is not serious because its principal effect is that of overcooling. At 30 miles an hour it is equivalent to running into a 23 mile head wind, and similarly lower wind at lower

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car speeds. If such wind should be detrimental in any testing it may be corrected by suitably throttling the air supply to the fan.

Measurement of car friction may be made by use of the generator as a motor. When this is done the traction scale reads the friction directly.

CAR WEIGHT AND ACCELERATION

In the foregoing discussion on rolling resistance, the assumption that the majority of cars on the road have substantially the same rolling resistance naturally presupposes that they agree similarly in weight, since tire losses increase directly with the load they carry. This is remarkably true since more than 57% of the cars on the road weigh within 150 lbs. of an average weight of 3250 lbs.⁸ and more than 95% deviate less than 500 lbs. from this average, or about the weight of three passengers. This is a practical matter of importance since car testing must be standardized with some arbitrary load, such as the weight of a driver, or the driver and one passenger, etc. Whatever condition is standardized will be dif-

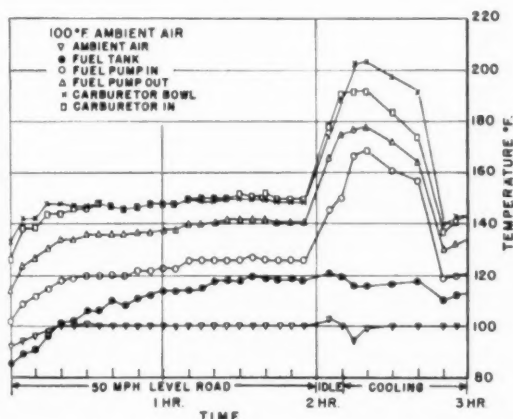


Figure 11 — Fuel system temperatures for a typical automobile at 50 miles an hour, and after stopping.

ferent from the loading which exists in many cars on the road.

The small variation in weight between most cars simplifies simulation of road loads on a chassis dynamometer, for acceleration time. It justifies building sufficient mass in the traction wheels to be equivalent to the mass of an average car. The acceleration of the average car will then be the same as on the road, except for such matters as the surge of gasoline in the carburetor and fuel system, etc., which usually have a negligible effect on car performance. The acceleration of cars with weights differing from the average will deviate from the accelerations on the road by quantities no greater than their deviations from the average weight. This may be corrected by multiplying the acceleration time by the ratio of the equivalent chassis dynamo-

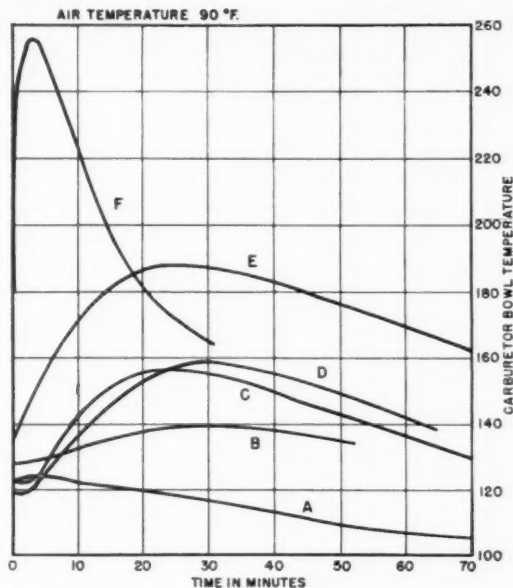


Figure 12 — Carburetor bowl temperatures of several automobile engines, after stopping from a 40 mile an hour speed in 90° air.

meter mass to the car mass. Such corrections for weight deviations up to 25% or about 800 lbs. appear acceptable, and are believed to justify the mechanical simplicity of a fixed built-in mass rather than adjustable masses with clutches. Furthermore, it is believed that where the mass is built in the traction wheels, it becomes an important factor in minimizing the wear on gears, universal joints, etc., because of reducing shock loading on these parts.

TRACTION WHEELS

The size of the chassis dynamometer traction wheels has frequently raised discussion. They have a circumference of 1/300 of a mile, so that 300 revolutions represented one mile. The diameter is

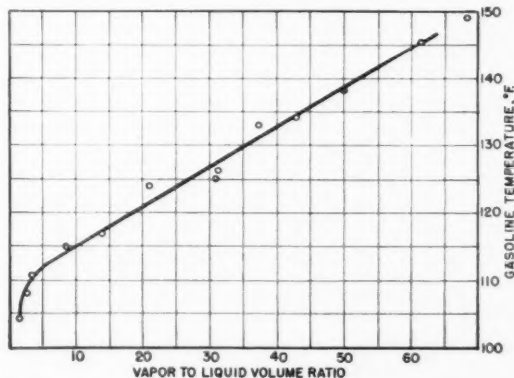


Figure 13 — Effect of temperature on the ratio of vapor to liquid volume for a typical winter grade gasoline.

therefore 5.60 feet, or $67\frac{1}{4}$ inches. This is the size used by the Automobile Club and on many later designs, including one at the U. S. Bureau of Standards. Most tire manufacturers test their tires on wheels of this size because it is written into Federal specifications for tires. The wheels have a width of $20\frac{3}{8}$ inches and are spaced on 4 feet 9 inch centers, so that cars may be tested which range from those with treads as small as 43 inches to those up to about 70 inches.

Calibration of the traction scale is accomplished by wrapping a steel tape around the traction wheel, and attaching weights. This is a very simple straightforward test. By reversing the tape so that the weights are applied on the opposite side of the wheel, a check is obtained on any reverse linkage which may be used.

CAR TESTING

As has been indicated earlier in this article, one of the important uses of a chassis dynamometer in an oil company laboratory, is to determine those characteristics of cars which affect their performance with various fuels and lubricants. To illustrate how extensive such data may be, a pair of routine performance sheets are included here as Figures 6 and 7, made up from values obtained by averaging

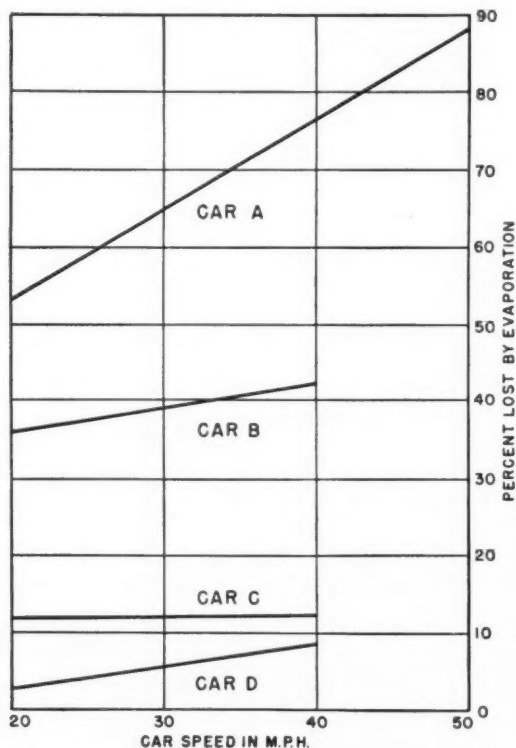


Figure 14 — Gasoline lost in carburetor bowl after car runs at various car speeds in 90° air.

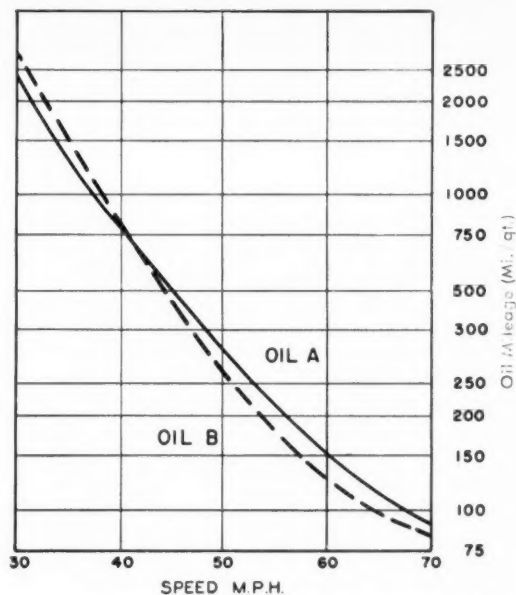


Figure 15 — Effect of car speed on oil mileage for two types of oil in one car.

data for 1948 Chevrolet, Ford and Plymouth passenger cars. Data have been collected on about a dozen of the largest production cars each year that cars were produced during the 17 years this chassis dynamometer has been in use. As a result a valuable store of data has been accumulated both on individual car characteristics which affect the fuels and lubricants which should be used, and on trends of automobile design as it has been changing from year to year.

A more specific application of a general average of a considerable number of cars is illustrated in Figure 8 which shows, first; that the level road fuel economy of the average automobiles at 40 miles an hour, has increased from about 15.5 to 19.5 miles per gallon in the 1935 to 1947 period. Secondly, this has been due but little to increased compression ratio since the rise of 0.5 compression ratio would have accounted for an increase to only about 17 miles per gallon. Lastly, by reference to the steady improvement in carburetion during this period, as shown at the right of this figure, it becomes evident that carburetion has been responsible for more of the improved miles per gallon than the compression ratio, although both have contributed.

Another interesting study showed the effect of spark advance on the percentage of engine power output. Figure 9¹ indicates the individual readings from 25 typical cars which are surprisingly consistent. From these the curve in Figure 10 was developed, which will apply to any normal automobile engine.

A considerable amount of car testing involves

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establishing normal temperatures in critical parts of the fuel and lubricating systems. This type of data is illustrated in Figure 11, which not only gives stable temperatures in various parts of the fuel system of a car while running steadily at 50 miles an hour, but reveals the characteristic rise in temperature of the critical parts of the fuel system, such as the carburetor bowl when the car is stopped. This is also indicated in Figure 12 for several cars, to show the wide differences between different car designs. The high temperatures of carburetor bowls are a serious matter to oil companies, who strive to provide their gasolines with a volatility which strikes a practical balance between easy starting and freedom from boiling in the fuel system, when a car is idled or stopped after a hard run. Figure 13 shows the large volume of vaporized fuel which results from heating a typical winter grade gasoline to various temperatures. For instance if the carburetor bowl is heated to 130°F., the gasoline in it will be vaporized to such an extent that the volume of vaporized fuel will be 35 times as great as the volume of the liquid passing through. Some provision must be made for venting this vapor from the carburetor bowl, or vapor pressure will build up and force so much liquid through the fuel jet that the engine cannot fire. Even with sufficient venting, if the metering jet is so hot that fuel boils while passing through it, the vapor bubbles will reduce the fuel flow and stall the engine with "vapor lock." This phenomenon is indicated in a different way in Figure 14 which shows the percent fuel lost through vaporization from the carburetor bowls of several cars when

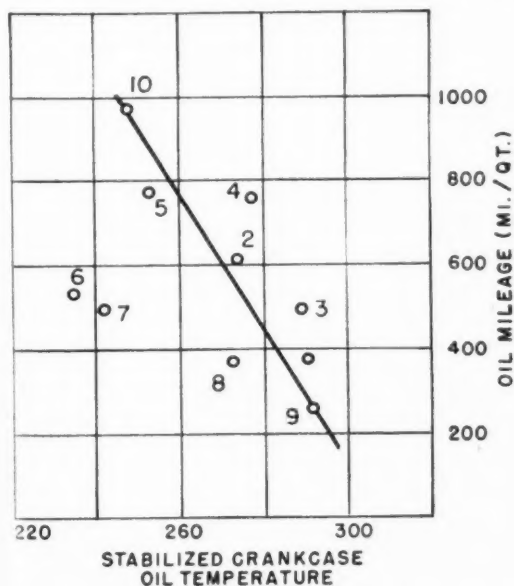


Figure 16 — Stabilized crankcase oil temperatures, and oil mileage of 10 different cars after runs at 60 miles per hour and 80 per cent load in 100° air.

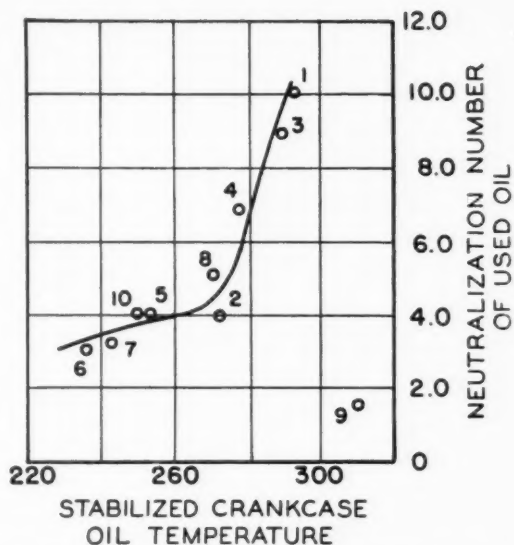


Figure 17 — Effect of crankcase oil temperature on oil deterioration as indicated by the neutralization number of the used oil from the same cars shown in Figure 16. Note the rapid rise where the temperature was above about 260° F.

stopped after runs at the speeds indicated in 90° air. The losses indicated for car A required cranking the engine 19 revolutions to refill the bowl after the 20 mile per hour run, and 31 after the 50 mile per hour run.

The effect of car speed on oil consumption is shown in Figure 15 for two different types of oil. These curves were for one specific car with higher oil consumption than for most cars when new, but it illustrates the rapid decrease of oil mileage with car speed which is characteristic of all cars. Car manufacturers have made great improvements in oil mileage during the past decade, which of course, imposes correspondingly greater need for oil stability because the oil is exposed to engine heat for longer periods. The wide variation between cars on oil performance as indicated by oil temperatures and consumption rate is revealed in Figures 16 and 17. These show the stabilized oil temperatures for 10, 1942 cars, after running at 60 miles an hour and at 80% full throttle load, in 100° air. The difficulty of running cars on the road at this speed long enough to reach steady oil temperatures is obvious, and runs at the same air temperature would be almost impossible. The wide variation between the oil temperatures of these cars is noteworthy. It will be seen that a rapid increase in oil deterioration as indicated by the neutralization number of the oil occurred when the oil temperature was above 260°. Some of the cars were thus much easier on the oil than others. Note that the oil consumption varied from 248 to 970 miles per quart. Except for two of the lowest priced cars the oil mileage of those in the remainder of this group decreased in the same order

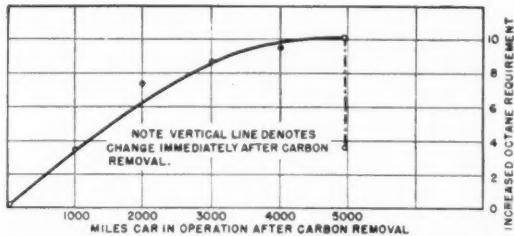


Figure 18—Average rise of octane requirement of several cars from engine deposits accumulated during normal operation.

as the oil temperatures increased. This is not implied to be the cause, but was probably another evidence of some general feature of engine design.

A few years ago an epidemic of corroded engine crankshaft bearings was reported from the field. Since these were reported as occurring only during high speed runs, test cars were run for 5 hour periods in 90°F. air at speeds of 60 or 70 miles an hour, depending on the car. This was sufficient to show that failure did occur with certain oil and bearing combinations, and that certain mechanical changes in engine design, or in the type of the lubricating oil, entirely corrected this trouble. In a similar way complaints of valve burning at high car speeds with certain types of oil have been studied by operating over a cycle of varying speeds including 75 miles an hour and then repeated for a total distance of several thousand miles.

From time to time anti-knock tests on cars are run by oil companies, in order to properly coordinate standardized laboratory engine anti-knock tests with them. Such work has usually been done on the road, starting with the famous Uniontown road tests in which practically all oil companies and many engine manufacturers participated. Such tests are often run at present on chassis dynamometers because they are more convenient and reproducible than such road tests. Such tests are now made by noting the absence or presence of knock when accelerating from 10 to 60 miles an hour with various spark advances. These tests are run by standardized procedure in a definite air temperature. One phase of this subject is shown in Figure 18 which indicates the average change in anti-knock requirement of several cars driven by their owners in normal use, as these requirements were affected by engine deposits. The steady rise during the first few hundred miles run after cleaning is characteristic, as is the plateau at which the anti-knock requirement stabilizes. At the end of the tests, the engines were decarbonized, and the drop in anti-knock requirement noted. It will be seen that this is higher than the start. This was due to changes in ignition timing, etc., which had occurred during these runs.

Besides such tests of more or less routine nature, many special projects are more conveniently solved on the chassis dynamometer than on the road or by

special laboratory set-ups of the car part to be tested. Such tests include those for rear axle gears to determine if they can stand severe loading without scuffing under repeated shock loading by sudden opening and closing of the throttle at speeds up to 80 miles an hour, using a new set of axle gears for each oil tested. Some of the new automatic transmissions impose entirely new requirements on their lubricants. The study of the cause for this, and its solution is a typical problem for the chassis dynamometer.

SUMMARY

The foregoing examples, indicate the general utility of a chassis dynamometer in studying many of the features of automobile design which affect the fuel and oil required for good performance. It is a device which not only offers more convenience in conducting tests than runs on the road but also it has additional advantages such as reproducible temperatures and continuous measurements of power developed, etc. Other factors of importance are those of offering the equivalent of unlimited straight and level roads for acceleration or continued high speed runs well above legal speed limits on highways, and performance on simulated hills of any desired gradient. This is a great convenience since such hills are surprisingly difficult to find when desired for test runs.

After seventeen years' experience with equipment of this type it has been found invaluable in adjusting the manufacture of petroleum products to meet the changing conditions imposed by the year to year evolution in automobile design, so that car owners have been assured of the best possible performance from their cars by use of fuels and lubricants which are tailored for their requirements.

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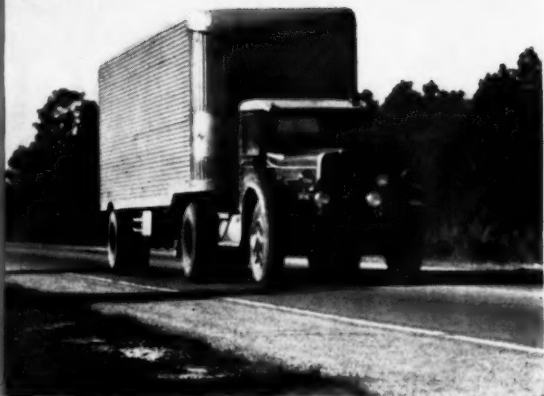


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